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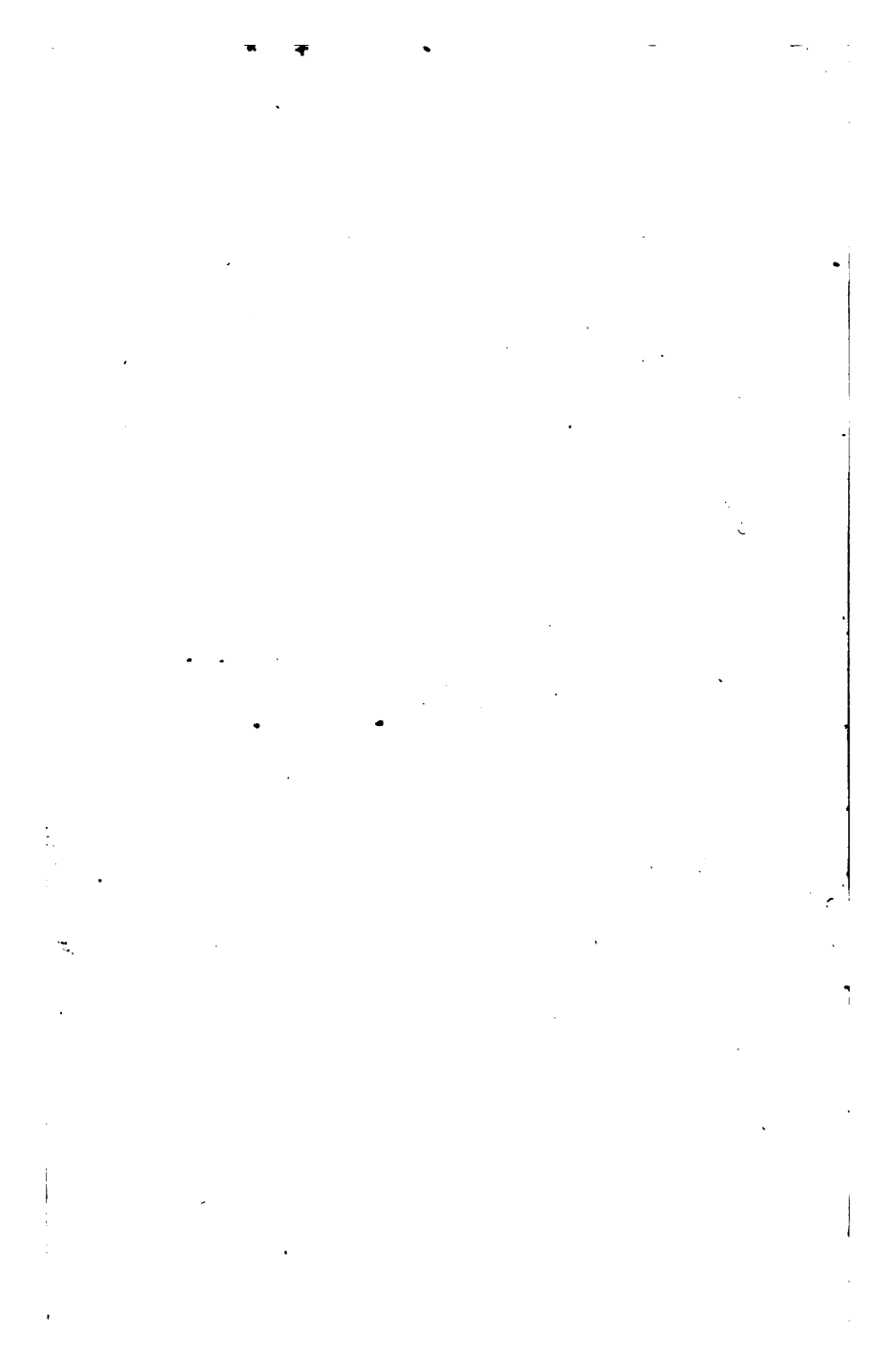
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◦ A

COMPENDIUM

OF

A S T R O N O M Y;

INTENDED

TO SIMPLIFY AND ILLUSTRATE THE PRINCIPLES
OF THE SCIENCE,

AND GIVE

A CONCISE VIEW OF THE MOTIONS AND ASPECTS
OF THE

GREAT HEAVENLY LUMINARIES;

ADAPTED TO THE USE OF

COMMON SCHOOLS,

AS WELL AS HIGHER SEMINARIES.

BY JOHN VOSE, A. M.

Late Principal of Pembroke Academy, N. H., and Author of a larger work
on Astronomy.

"CREATION OF ARCHANGELS IS THE THEME.".....*Dr. Young.*

Stereotype Edition.

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PREFACE.

THE improvements in the education of youth, the taste for mental culture generally diffused, and particularly the facilities introduced for commencing study at a much earlier period of life than formerly, render it important that the circle of knowledge to be acquired should be greatly enlarged. Every enlightened citizen and well-wisher to the rising generation must perceive that the march of improvement requires the arts and sciences emphatically termed *liberal*, to be introduced into our *common schools*. Here a large proportion of the community complete their education.

Among the sciences, Astronomy, most happily adapted to enlarge and elevate the mind, must hold a distinguished place. When its importance, as the foundation of other arts and sciences, and the grandeur of the objects brought into view, are considered, it must be wonderful that it has not been more generally introduced.

In the following Compendium of Astronomy, it has been the aim of the author to render the principles of the science so simple, that they may be easily understood; not only by the scholar who spends a few weeks at an academy, but by him whose means and views do not carry him beyond the *common school*.

The questions at the close of the chapters and sections are intended to aid the teacher, and not to prevent *his own*, which ought to be often proposed. The questions inserted are important in reviews.

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INTRODUCTION.

THE term ASTRONOMY, like most terms of science, is derived from the ancient Greek language. *Astronomia*, astronomy, is compounded of *astron*, a star or constellation, and *nomos*, a law, the law of the stars. It may be defined the science which treats of the heavenly bodies.

Astronomy is a science of great antiquity. Its early history has too many allegorical representations to admit of a satisfactory elucidation. It is, however, probable, that some scanty knowledge of this science must have been nearly coeval with the existence of man. The grandeur of the delightful canopy extended over his head, must have attracted the curiosity of the most careless and rude wanderer of the forest, much more of the attentive shepherd. Besides, the common concerns of life are in some measure regulated by a partial knowledge of astronomy.

Both the Chaldeans and Egyptians claimed a very high antiquity; and equally claimed the honor of being the first cultivators of astronomy. It may not be easy, at this late day, to determine which has the best founded claim. Most authors seem agreed in fixing the origin of this science either in Chaldea or Egypt. The shepherds, who "watched their flocks

by night," on the beautiful plains of Babylon, or in the extended vale of the Nile, could not be careless spectators of the varying aspects of the heavens. The tower of Belus was the boast of the Chaldeans. This is thought by some to have been an astronomical observatory. They gloried in their astronomer, Zoroaster, placed by them 500 years before the destruction of Troy. The Egyptians, with equal ostentation, vaunted of their priests. The colleges of these they considered as the depositaries of every species of knowledge. In the monument of Osymandyas, it is said, there was a golden circle of 365 cubits in circumference, divided into 365 equal parts, according to the days of the year, with the heliacal rising and setting of the stars for each day. It is proper to state, that, whatever may be thought of the tower of Belus, or the circle of Osymandyas, both the Chaldeans and Egyptians were extremely well situated for astronomical observations, being almost always favored with a pure atmosphere, and a sky of delightful serenity. A very favorable opinion of the Egyptians must be formed from the position which they gave to their pyramids, the faces of these being accurately directed to the four cardinal points of the heavens.

Besides the Chaldeans and Egyptians, the Arabians may justly claim a high antiquity in astronomical knowledge. The land of Uz, famous for the afflictions of Job, was without doubt a district of Arabia. Authors are agreed, that the book of Job is very ancient—is unrivalled in antiquity, except, perhaps, by the books of Moses. From the familiar manner in which *Arcturus*, *Orion*, and *Pleiades*

are introduced in that book, it may be ascertained, that not only were names given to some of the stars, but constellations had been designated and named, so as to become objects of general notoriety.

“Among other relations of this kind may be reckoned what is mentioned by Josephus in his *Antiquities*, who, in speaking of the progress that had been made in astronomy by Seth and his posterity, before the deluge, asserts, that they engraved the principles of the science on two pillars, one of stone and the other of brick, called the pillars of Seth; and that the former of these was entire in his time. He also ascribes to the antediluvians a knowledge of the astronomical cycle of 600 years, which Mantucla, in his *Historie des Mathematiques*, thinks, with much greater reason, was an invention of the Chaldeans; and that whatever information was possessed by the Jewish annalist, with respect to this memorable period, was probably obtained either from that people, or from some ancient writings which no longer exist.”

Astronomy is a science useful and sublime in the highest degree. It is useful, not only on its own account, but as the foundation of other arts and sciences; and sublime, as it elevates the soul above the little objects of this world to scenes of infinite grandeur.

Navigation, as an art or a science, is dependent on the principles of astronomy. The varying compass would not form a sure guide to the mariner on the pathless ocean, were it not for corrections derived from observation on the heavenly bodies. Geography is equally dependent. By astronomy

are ascertained the figure and magnitude of the Earth. The knowledge of latitude and longitude, the situation and distance of places the most remote, the true bearing of countries in respect to each other, and their magnitude or extension, are most accurately obtained by astronomical principles. But above all, astronomy affords the most enlarged and sublime views of the Creator's works. In the vast expanse of the universe, the astronomer beholds the stars, which bespangle and adorn our canopy, magnified into so many suns, surrounded with worlds of unknown extent, constituting systems multiplied beyond the utmost bound of human imagination, and measured only by the omnipresence of Jehovah; all moving in harmony, in subjection to his omnipotent control. "*The heavens declare the glory of God, and the firmament showeth his handy work.*" "An undevout astronomer is mad."

There have been three great systems of astronomy—the Ptolemaic, the Brahean, and the Copernican. The former two, however, though dignified by the name of *systems*, are more properly denominated *hypotheses*.

The Ptolemaic system takes its name from Claudius Ptolemeus, or Ptolemy, who flourished at Alexandria or Pelusium in Egypt, in the second century of the Christian era, in the reigns of Adrian and Antoninus, the Roman emperors. In this system, the Earth was supposed at rest in the centre of the universe, around which the Moon, Mercury, Venus, the Sun, Mars, Jupiter and Saturn revolved. Above the planets this hypothesis placed the firmament of stars and the two crystalline spheres, all

included in the *primum mobile* giving motion to the whole. Still higher, according to some, he conceived, was placed the *empyrium heaven*, or heaven of heavens; all revolving round the Earth from east to west in twenty-four hours, according to the ideas of the illiterate in all ages. (Plate 1. Fig. 1.)

The different phases of Mercury and Venus, their superior conjunctions without oppositions, and the apparent retrograde motion of all the primary planets, show the absurdity of this hypothesis.

Tycho Brahe was a native of Sweden, being born at Knudstorp, in the year 1546; though, from education and residence in Denmark, considered a Dane. This celebrated astronomer was acquainted with the Copernican system, published before his time. But, rejecting some of its most simple principles, because he thought them irreconcilable to the literal meaning of some texts of scripture, he adopted some of the greatest absurdities of Ptolemy, in other respects making his system agree with the rules of modern astronomy.

In his system the Earth is supposed at rest, the Sun and Moon revolving round it as the centre of their motion, while the other planets revolve around the Sun, and are carried with it about the Earth. (Plate 1. Fig. 2.)

By this hypothesis the phases of Mercury and Venus may be explained. But no satisfactory explanation can be given by it of the opposition of the superior planets. Both the Ptolemaic and Brahean systems are contrary to the modern principles of calculating and projecting eclipses.

The Copernican system is now universally adopt-

ed by astronomers as the true *solar system*. Some of the ancient Egyptians discovered the revolution of Mercury and Venus round the Sun. The general principles of the system were afterwards taught privately by Pythagoras to his disciples, five hundred years before the Christian era. But, being afterwards rejected, it was nearly lost, till revived by Copernicus, a native of Thorn, in Polish Prussia. In the centre of this system is placed the Sun, around which the primary planets revolve from west to east. The Earth turns on its axis. The Moon revolves round the Earth. The other secondary planets perform their revolutions around their primaries from west to east, at different distances and at different times, the satellites of Herschel only excepted. Beyond these, at an immense distance, are the fixed stars, as centres to other systems. (Plate 1. Fig. 3.*)

Some authors inform us, that Copernicus finished his great work in 1530; but did not venture it in print till near the time of his death, which happened on the twenty-second of May, 1543. He died suddenly, by the rupture of a blood-vessel, soon after completing his seventieth year, and a few days after revising the first proof of his work.

Copernicus was an accurate mathematician, and applied his useful knowledge to the improvement of astronomy. Perplexed with the epicycles and ec-

* In this figure, the orbits are delineated, nearly as possible, according to their elliptical form, and in due proportion. The stars of the zodiac are placed according to their true situation in the celestial zone. In the diagrams of some works, the orbits of the inferior planets are represented greatly enlarged beyond their proper dimensions.

centrics, by which Ptolemy attempted to account for the irregular motion of the heavenly bodies, he searched the lore of antiquity. "He tried to find among the ancient philosophers a more simple arrangement of the universe. He found, that many of them had supposed Venus and Mercury to move round the Sun; that Nicetas, according to Cicero, made the Earth revolve on its axis, and by this means freed the celestial sphere from that inconceivable velocity, which must have been attributed to it to accomplish its diurnal revolution. He learned from Aristotle and Plutarch, that the Pythagoreans had made the Earth and planets move round the Sun, which they placed in the centre of the universe. These luminous ideas struck him. He applied them to the astronomical observations, which time had multiplied, and had the satisfaction to see them yield, without difficulty, to the theory of the motion of the Earth. The diurnal revolution of the heavens was only an illusion due to the rotation of the Earth, and the precession of the equinoxes is reduced to a slight motion of the terrestrial axis. The circles, imagined by Ptolemy, to explain the alternate, direct and retrograde motions of the planets, disappeared. Copernicus only saw in these singular phenomena the appearances produced by the motion of the Earth round the Sun with that of the planets; and he determined, hence, the respective dimensions of their orbits, which till then were unknown. Finally, every thing in this system announced that beautiful simplicity in the operations of nature, which delights so much when we are fortunate enough to discover it. Copernicus pub-

lished it in his work *On the Celestial Revolutions*. Not to shock received prejudices, he presented it under the form of an hypothesis. "Astronomers," said he, in his dedication to Paul III, "being permitted to imagine circles, to explain the motion of the stars, I thought myself equally entitled to examine, if the supposition of the motion of the Earth would render the theory of these appearances more exact and simple."

From what is the term *astronomy* derived? Of what is it compounded? How long has the science of astronomy been cultivated? What nations claim the honor of being the first astronomers? At what time did the astronomer Zoroaster live? What was in the monument of Osymandyas? Why were both Chaldea and Egypt peculiarly favorable for astronomical observations? What other nations may claim a high antiquity in the science of astronomy? Where was the land of Uz? For what was it distinguished? Why are we to suppose from the book of Job that the Arabians were astronomers? What does Josephus say concerning the knowledge of astronomy before the deluge? What were the pillars of Seth? By whom was the astronomical cycle of 600 years invented? On what account is astronomy useful? Why is navigation dependent on astronomy? Why geography? Why does it afford a sublime view of the Creator's works? What noted systems of astronomy have there been? From what does the Ptolemaic take its name? What was it? What shows the absurdity of this hypothesis? Who was Tycho Brahe? Why did he reject the Copernican system? What was the Brahean system? What cannot be explained by the Brahean system? Which is the true solar system? By whom and when was this first taught? Who was Copernicus? How are the heavenly bodies arranged in his system? When did Copernicus finish his work? What led him to consider other systems absurd? What did he discover by investigation? Under what form did he present his system?

A GLOSSARY

OF ASTRONOMICAL TERMS.

Altitude is an arch of a vertical circle intercepted between the centre of a heavenly body and the horizon.

Amplitude is the distance of a heavenly body from the east or west point of the horizon, measured on an arch of that circle, the body being in it, or referred to it by a verticle.

Antipodes, inhabitants living at opposite points of the Earth's surface, under opposite meridians and in opposite parallels.

Antæci, inhabitants living under the same meridian, but in opposite parallels, north and south.

Aphelion, the point in the orbit of a planet farthest distant from the Sun.

Apogee, the point in the Moon's orbit most distant from the Earth. The term is sometimes applied to the Sun's place when farthest from the Earth.

Apsis, the aphelion or perihelion point. The line connecting these is called the *line of the apsides*.

Arch of a circle, a part or portion of the circumference.

Asteroids, four small planets between Mars and Jupiter.

Axis, an imaginary line on which the Sun or a planet revolves.

Azimuth, the distance of a heavenly body from the north or south point of the horizon, when the body is in that circle, or referred to it by a verticle.

Centrifugal force, that by which a revolving body endeavors to recede from the centre of its motion.

Centripetal force, that which attracts a revolving body to the centre.

Comet, a celestial body moving round the Sun in an orbit very eccentric.

Conjunction, the meeting of heavenly bodies in the same longitude, on the same side of the Earth, though they may not be in the same latitude.

Constellation, a number of stars contained in an assumed figure.

Cosines, cotangents, and cosecants, are sines, tangents, and secants of the complement of an arch.

Cycle, a period of time.

Declination, the angular distance of a heavenly body from the equator.

Dichotomized, divided into two parts.

Disk of the Sun or a planet, the hemisphere presented to an observer, appearing like a plain circle.

Eccentricity, the distance in a planet's orbit between one of the foci and the centre.

Eclipse, a partial or total obscuration of a heavenly body.

Ecliptic, a great circle in which the Earth performs its annual revolution round the Sun; or in which the Sun appears to revolve round the Earth.

Elongation, the angular distance of a heavenly body from the centre of its motion; as a planet from the Sun, or a secondary from its primary.

Epact, the excess of the solar above the lunar year of 354 days, or 12 mean lunations.

Equator, a great circle of the Earth drawn round the centre from east to west.

Equinox, a point in the ecliptic, where it is cut by the equator. There are two equinoxes, the vernal and autumnal.

Focus, a point in the elliptical orbit of a planet, round which it revolves.

Foci, the plural of *focus*, two points in the transverse axis of a planet's orbit.

Galaxy, the milky way.

Geocentric motion, the apparent motion of a planet as seen from the Earth.

Gibbous, convex, protuberant; applied to the Moon between the first quarter and the full, or between the full and last quarter; also applied to some of the planets.

Globe, a sphere representing the Earth or visible heavens.

Golden number, a period of 19 years; the cycle of the Moon.

Heliocentric motion, the motion of a planet as seen from the Sun.

Hemisphere, half of a sphere or globe.

Horizon, a great circle of the Earth, 90° from the zenith of a place, the plane of which divides the Earth into upper and lower hemispheres. This is denominated the *rational* horizon. The *sensible* horizon is the circle which bounds our sight.

Inclination, the angular distance between the orbit of a planet and the ecliptic.

Latitude of a heavenly body, its distance north or south from the ecliptic.

Latitude, on the Earth, the distance north or south from the equator.

Libration of the Moon, a periodical irregularity in her motion, by which exactly the same face is not always presented to the Earth.

Limits in a planet's orbit, two points farthest distant from the nodes.

Longitude of a heavenly body, its distance on the ecliptic from the first of Aries to the intersection of a secondary passing through the body. It is reckoned eastward 360° .

Longitude on the Earth, the distance east or west from a fixed meridian.

Meridian, a great circle of the sphere, encompassing the Earth from north to south. Half of this is sometimes called a *meridian*.

Nadir, the point in the heavens directly under the observer, and opposite to the zenith.

Nebulae, telescopic stars cloudy in appearance.

Node, a point at which the orbit of a planet crosses the plane of the ecliptic. The intersection where the planet passes to the north is denominated the ascending node; where it passes to the south, the descending node; *above* being often used for north, and *below* for south, in astronomical terms.

Oblate spheroid, a spherical body flattened at the poles.

Obliquity, inclination, the angular distance of a circle from the ecliptic.

Oblique sphere, a position of the sphere, in which the equator and parallels cross the horizon in an oblique direction.

Opposition, opposite part of the heavens. Two bodies are said to be in opposition, when their distance of longitude is 180° , though they may not be in the same degree of celestial latitude.

Orbit, the figure described by a planet in its revolution round the Sun, or its primary.

Parallax, the angular difference between the true and apparent place of a heavenly body.

Parallel sphere, a position of the sphere, in which the parallels of latitude and the equator appear parallel to the horizon.

Penumbra, the partial shadow of the Moon.

Perigee, the point in the Moon's orbit nearest to the Earth; sometimes applied to the place of the Sun, when nearest to the Earth.

Perieci, inhabitants in the same parallels, but under opposite meridians.

Perihelion, the point in the orbit of a planet nearest to the Sun.

Phases, the different appearances of the Moon, Mercury and Venus, as the illuminated side is differently presented to a spectator.

Phenomenon, appearance, often a novel appearance.

Phenomena, plural of *phenomenon*.

Planet, a heavenly body revolving round the Sun, or some primary planet.

Plane of a planet's orbit, that imaginary surface in which it lies; or a supposed even surface between every part of its circumference.

Polar circles, two circles drawn round the Earth from east to west, parallel to the equator, about $23^{\circ} 28'$ from the poles.

Poles of a planet or the Sun, the extremities of its axis.

Precession of the equinoxes, their retrograde motion in the heavens.

Primary planets, those which perform their revolutions immediately round the Sun.

Projectile force, that which impels a body in a right line.

Quadrature, a quarter, a point in the celestial sphere 90° from the Sun.

Quadrant, the fourth part of a circle.

Radius, a right line from the centre of a circle to the circumference.

Refraction, the turning of a ray of light from a straight course.

Retrograde motion, apparent motion from east to west.

Right angle, 90° . When a line falls on another line, making the angles on each side equal, each is a right angle.

Right ascension, the distance of a heavenly body from the first of Aries on the equator, or referred to that circle by a secondary. It is reckoned from the first of Aries to the point where the secondary, passing through the body, cuts the equator.

Secondary planets, satellites or moons, small planets revolving round some of the primary planets.

Secondary to a great circle, a great circle crossing it at right angles.

Sidereal revolution, the time of a planet's revolving from a star to the same star again.

Sine, a line drawn from one end of an arch perpendicular to the radius.

Solstices, two points in the ecliptic, 90° from the equinoxes.

Star, a luminous heavenly body shining by its own light.

Synodical revolution, the time intervening between the conjunction of a planet with the Sun, and the succeeding conjunction of the same bodies.

Syzygy, the conjunction or opposition of a planet with the Sun; as the change or full of the Moon.

Tangent, a right line touching the circumference of a circle perpendicular to the radius.

Tide, the alternate ebbing and flowing of the sea.

Transverse, the longest axis of an ellipse.

Tropical revolution, the time intervening between a planet's passing a node and coming to the same node again.

Tropics, two circles parallel to the equator, at the distance of about $23^{\circ} 28'$.

Twilight, crepusculum, the partial light before sunrise in the morning and after sunset in the evening.

Vector radius, a line from a planet, in any part of its orbit, to the Sun.

Vertical circles, circles cutting the horizon at right angles, and passing through the zenith and nadir of a place.

Zenith, the point in the heavens directly over the observer. The zenith and nadir are the poles of the horizon.

Zodiacal light, a pyramid or triangular beam of light, rounded a little at the vertex, appearing before the twilight of the morning and after the twilight of the evening.

Zodiac, a broad circle in the heavens between two lines on each side of the ecliptic, and parallel to it at eight degrees distance.

Zone, literally a belt or girdle; a large division of the Earth's surface.

CHARACTERS.

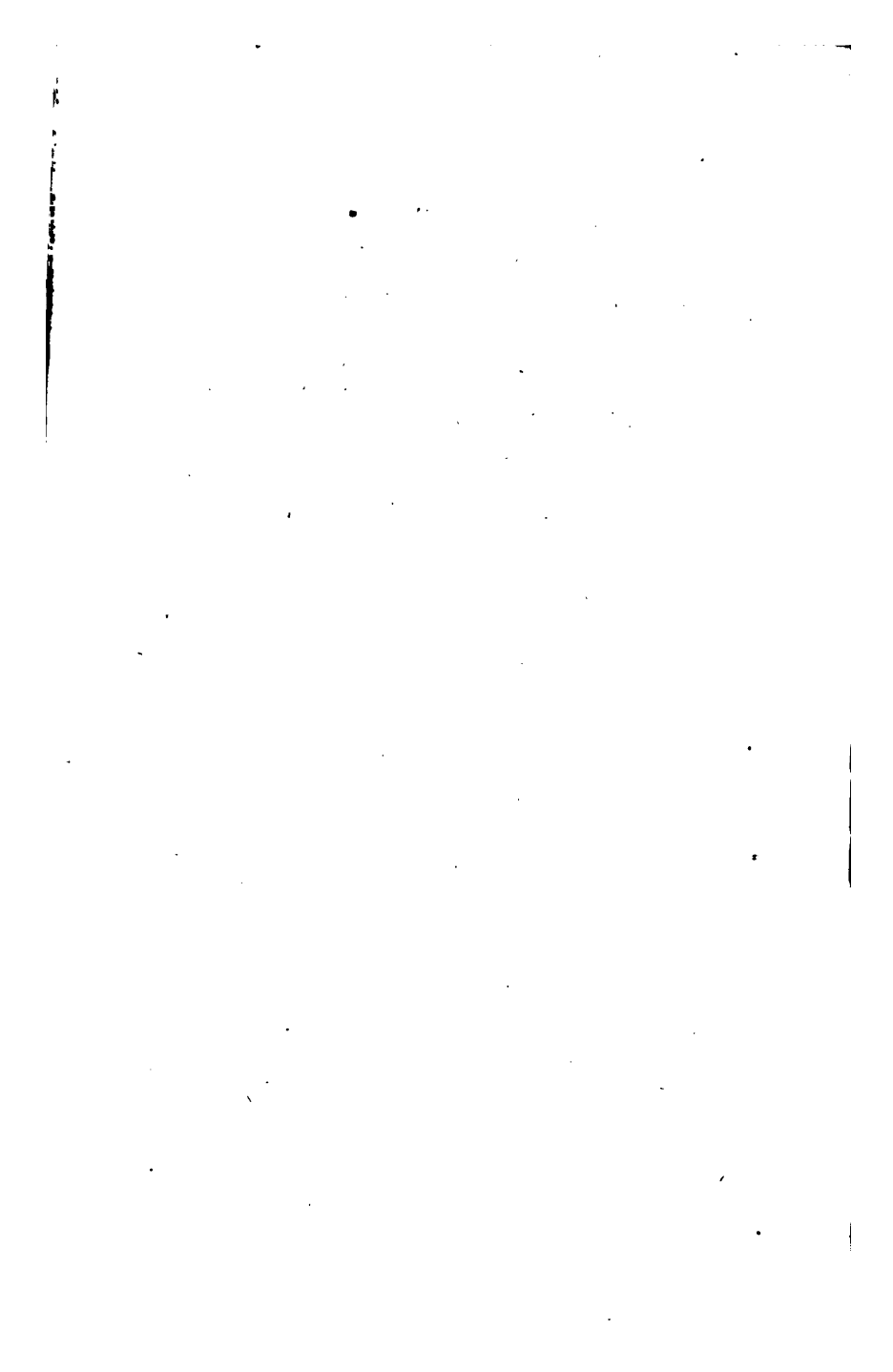
PLANETS.

α	Mercury.	ζ	Ceres.
\odot	Venus.	\diamond	Pallas.
\oplus	Earth.	\jmath	Jupiter.
\otimes	Mars.	♄	Saturn.
♁	Vesta.	♅	Herschel.
♁	Juno.		

SIGNS.

♈	Aries.	♎	Libra.
♉	Taurus.	♏	Scorpio.
♊	Gemini.	♐	Sagittarius.
♋	Cancer.	♑	Capricornus.
♌	Leo.	♒	Aquarius.
♍	Virgo.	♓	Pisces.

S	Sign.
°	Degree.
'	Minute.
"	Second.
'''	Third.
=	Equality.



ASTRONOMY.

CHAPTER I.

SECTION I. *The Solar System.*

THE SUN with his attendant planets and comets constitute the *solar system*.

Conceive a large gilt ball suspended in open space, with several smaller balls moving around it from west to east, at different distances and with unequal velocity; imagine those nearest the large ball to have the swiftest motion, and that the movement of the others is more and more slow, as you pass to those most remote; imagine further, that several of the revolving balls have others moving round them, and carried with them, or round the central ball, and that all these motions are perpetual, and you will have some imperfect idea of the *solar system*. The idea will be more complete, if occasionally a ball with a fiery train, or tail, be conceived moving with great velocity in a direction nearly to the central ball; but that, passing round this, it recedes with retarded motion, the train increasing as it draws towards the centre, and diminishing as it recedes.

It is important that every instructor in astronomy should be furnished with an orrery. In want of this, balls may be formed of soft materials. But the whole may be supplied by a fruitful imagination. This alone may bear the student from the balls or the orrery to the great heavenly bodies, their movement, and distances. To give a clear view of the whole, as suspended and re-

volving in infinite space, is an object deserving the assiduous care of the well-informed teacher.

What constitute the solar system? How may the solar system be represented? What may supply the place of an orrery?

SECTION II. *Of the Sun.*

The Sun is the great source of light and heat to the bodies of the solar system. It is an object pre-eminent; of inconceivable utility and grandeur. Diffusing its rays to an immense distance, and filling a sphere of incomprehensible extent, it gives life and motion to innumerable objects. In some humble measure it resembles its Divine Author. The most minute beings are not overlooked; the greatest are subject to his control.

The Sun is considered in the lower focus of the planetary orbits. But if the centre of the Sun be considered the focus of Mercury's orbit, the common centre of gravity between Mercury and the Sun will be the focus of Venus's orbit; and the common centre of gravity between Mercury, Venus, and the Sun will be the focus of the Earth's orbit. Thus the attraction of the planets nearest the Sun will in a small degree affect the foci of those more remote. Except the foci of Saturn and Herschel, however, those of all the orbits will not be sensibly removed from the centre of the Sun. Nor will the foci of Saturn and Herschel be sensibly different from the common centre of gravity between Jupiter and the Sun.

Though stationary in respect to surrounding objects, the Sun is not destitute of motion. It revolves on its axis from west to east in 25 d. 15 h. 16 m., or, according to some authors, in 25 d. 10 h. The Sun's rotation is known from the revolution of its spots.

The form of the sun is globular. This is demonstrable from its always appearing a flat, bright circle, whatever side is presented to the observer. The diameter

of the Sun is 883,246 miles ; its circumference 2,774,897 miles. The Sun is 1,364,115 times larger than the Earth. Thus, surpassing in greatness the globe we inhabit more than $1\frac{1}{2}$ million times, it swells beyond our conception. Some imperfect idea of the immense magnitude of the Sun may be formed by one or two computations. A celestial courier, passing at the rate of forty miles a day, would be about 190 Julian years in circumambulating the Sun. If the Sun were a hollow globe, and the Earth placed at its centre, the Moon, at its present distance from the Earth, 240,000 miles, might revolve uninterrupted, being but little more than half way from the centre to the circumference of the Sun. Such a hollow globe might, therefore, contain within itself a brilliant system of revolving worlds.

The physical construction of the Sun has excited much inquiry and speculation. From time immemorial, an opinion seems to have prevailed, that the Sun was a globe of fire. Some say, "The Sun shines, and his rays, collected by concave mirrors, or convex lenses, burn, consume, and melt the most solid bodies, or else convert them into ashes or gas ; wherefore, as the force of the solar rays is diminished by their diverging, in a duplicate ratio of the distances reciprocally taken, it is evident their force and effect are the same, when collected by a burning lens or mirror, as if we were at such a distance from the Sun, where they were equally dense. The Sun's rays, therefore, in the neighborhood of the Sun, produce the same effects as might be expected from the most vehement fire ; consequently, the Sun is a fiery substance." The force of this reasoning would lead us to conclude, that, however antiquated or repudiated the opinion may be, that the Sun is a globe of fire, its surface must resemble a vast combustion.

But if heat come from the Sun, or the moving cause of heat originate in that luminary, why is it always cold in the upper regions of the air, though nearer the Sun than the surface of the Earth ? and why are the tops of lofty mountains covered with perpetual snow, even un-

der the equator? The reply is, that animal heat is generated in the lungs from the oxygen of the atmosphere; that air is a bad conductor of heat, and of course a good defence against cold, or rather preservative of heat, preventing its escape from the body. The more dense the air is, therefore, the warmer is any situation.

The density of the atmosphere is considered as decreasing in a geometrical proportion upwards from the surface of the Earth. If the decrease be not always thus proportioned, it is well ascertained by experiments on the tops of lofty mountains, that the air becomes very rare in high regions. Hence the supply of heat from the oxygen of the atmosphere, and the security against cold, or the preservation of heat from the non-conducting power of the air, are greatly diminished. This must affect sensation, and in some degree the thermometer. But this is not the only cause, perhaps not the principal cause, why high regions of the air are cold. According to chemists, all bodies, even those to us the most frigid, radiate heat. Hence, on the common surface of the Earth, not the great mass of the globe only, but other bodies innumerable, with which we are surrounded, supply us with heat. But the elevated observer on the top of Chimborazo or Himmaleh is retired, in some measure, above the influence of the Earth, and the bodies on its surface. He must exhaust his own treasure of heat, while, except immediately from the Sun, he can receive next to nothing in return. It may be added, that heat, or caloric, is by very many considered a fluid put in action by the Sun's rays. If so, it may be confined near the surface of the Earth, or be far short of the atmosphere in height. On the modern theory of caloric, therefore, elevation must greatly diminish, rather than increase the heat.

The highest elevation to which human beings can ascend, though quite a proportion in regard to the height of the atmosphere, vanishes, when compared with the distance of the Sun. What are four or five miles in comparison to ninety-five millions! No mountain is so

elevated, no balloon can ascend so high, as to make any perceptible difference in respect to the distance of the Sun.

In regard to the ancient theory, it is worthy of notice, that the powerful attraction of the Sun is incompatible with its being a mass of *flame* only, and the spots on its surface are conclusive, that in part, at least, it must be composed of other matter.

The celebrity of Dr. Herschel, and the ingenuity of his hypothesis respecting the Sun, make this hypothesis deserve some particular consideration. Rejecting the terms *spots*, *nuclei*, *penumbrae*, *faculae*, and *luculi*, he adopts *openings*, *shallows*, *ridges*, *nodules*, *corrugations*, *indentations*, and *pores*. *Openings*, he says, are those places, where, by the accidental removal of the luminous clouds of the Sun, its own solid body may be seen; and this not being lucid, the openings, through which we see it, may, by a common telescope, be mistaken for mere black spots.

Shallows are extensive and level depressions of the luminous solar clouds, generally surrounding the openings to a considerable extent. Being less luminous than the rest of the Sun, they seem to have some very imperfect resemblance to *penumbrae*, which occasioned them formerly to be so called.

Ridges are elevations of luminous matter, extended in rows of irregular arrangement.

Nodules are also elevations of luminous matter, but confined in extent to a small space. Those ridges and nodules, being brighter than the general surface of the Sun, and slightly differing from it in color, have been called *luculi* and *faculae*.

Corrugations are a remarkable unevenness or asperity, peculiar to the luminous clouds, extending over the whole apparent surface of the Sun. The depressed parts of the corrugations being less luminous than those more elevated, the disk of the Sun has a variegated or "mottled" appearance.

Indentations are the low or depressed parts of the corrugations.

Pores are very small openings about the middle of the indentations.

By a number of observations he would evince, that the appearances, called *spots*, in the Sun, are real openings in the luminous clouds of the solar atmosphere.

His next series of observations is adduced to prove, that the appearances, which have been called *penumbrae*, are real depressions, or shallows. Following these are others, alleged to show, that ridges are elevations above the luminous solar clouds; that nodules are small but highly elevated luminous places; that corrugations consist of elevations and depressions; that indentations are dark places of the corrugations; and that pores are the low places of indentations. He hence infers, that the several phenomena, above enumerated, could not appear, if the Sun's shining matter were a liquid; since, by the laws of hydrostatics, the openings, shallows, indentations, and pores, would instantly be filled up; and ridges and nodules could not preserve their elevation a single moment. But many openings have been known to last during a whole revolution of the Sun; and elevations large in extent have continued for several days. Much less can this shining matter be an elastic fluid of an atmospheric nature; because this would be still more ready to assume a level by filling up the low places. It must therefore exist in the manner of luminous, empyreal, or phosphoric clouds, suspended in the higher regions of the solar atmosphere.

"It appears highly probable," says Dr. Brewster, "and consistent with other discoveries, that the dark solid nucleus of the Sun is the magazine, from which its heat is discharged, while the luminous or phosphorescent mantle, which that heat freely pervades, is the region whence its light is generated." The high authority of these men does not free their hypotheses from objection. If the spots are openings only in the luminous clouds of the Sun, why are they stationary for so long a time, except as they partake of the Sun's rotation; and why should heat be emitted from the dark body of the Sun, and not

from its luminous mantle, when that mantle has so much the appearance of flame, from which heat is generally diffused on the earth? But investigations into the nature of the Sun must be attended with so much uncertainty, that perhaps no theory on the subject can be free from objection.

Much light has been thrown upon heat or caloric by the improvements of modern chemistry. But satisfactory conclusions concerning its *nature* cannot be drawn. Lord Bacon considered heat "the effect of an intestine motion, or mutual collision of the particles of the body heated, an expansive undulatory motion in the minute parts of the body." Count Rumford's experiments seemed to show, that caloric "was imponderable, and capable of being produced *ad infinitum* from a finite quantity of matter." He concluded, that "it must be an effect arising from some species of corpuscular action amongst the constituent parts of the body." Other chemists consider it "an elastic fluid *sui generis*."*

Mr. Dick, a Scotch author of much ingenuity, in his Christian Philosopher, has a note on the planet Mercury, deserving consideration. "From a variety of facts, which have been observed in relation to the production of *caloric*, it does not appear probable, that the degree of heat on the surfaces of different planets is inversely proportional to the square of their respective distances from the Sun. It is more probable, that it depends chiefly on the distribution of the *substance of caloric* on the surfaces, and throughout the atmospheres of these bodies, in different quantities, according to the different situations they occupy in the solar system; and that these different quantities of caloric are put into action by the influence of the solar rays, so as to produce that degree of *sensible* heat requisite for each respective planetary globe. On this hypothesis, which is corroborated by a great variety of facts and experiments, there may be no more sensible heat felt on the surface of the planet

* Of its own kind.

Mercury, than on the surface of Herschel, although one of these bodies is nearly fifty times nearer the Sun than the other. We have only to suppose, that a small quantity of caloric exists in Mercury, and a larger quantity in Herschel, proportionate to his distance from the centre of the system. On this ground, we have no reason to believe, either that the planets nearest the Sun are parched with excessive heat, or that those that are most distant are exposed to all the rigor of insufferable cold ; or that the different degrees of temperature which may be found in these bodies, render them unfit for being the abodes of sensitive and intellectual beings."

This theory of *caloric* is modern and popular ; but, like others on the same subject, does not command unqualified assent. If heat be a fluid only, why is it *radiated* by all bodies ? and why, reflected, does it pass from object to object in *rays*, a manner so dissimilar to the movement of other fluids ? It may be that the learned world must be content, as in attraction, with knowing the operations of heat, without being able to investigate its nature.

Any uncertainty respecting caloric, must rest on the physical construction of the Sun, the prime agent of heat in whatever way produced. From what has been said of solar clouds, it must be apparent that some authors consider the Sun surrounded by an atmosphere of vast extent. They ground their opinion principally on the authority of Dr. Herschel, supported by his observations. "The height of the atmosphere he computes to be not less than eighteen hundred forty-three, nor more than two thousand seven hundred sixty-five miles, consisting of two regions ; that nearest the Sun being opaque, and probably resembling the clouds of our Earth ; the outermost emitting vast quantities of light, and forming the apparent luminous globe we behold."

Harriot, an Englishman, or Fabricius, a German, first discovered the spots on the Sun, about the year 1610. According to some authors, they were first seen by Galileo, or Scheiner. An account of his observations on

them was published by Fabricius in 1611. The spots are various in shape and magnitude. Some have been observed large enough to cover the whole eastern continent, Europe, Asia, and Africa ; some to cover the surface of the whole Earth ; and one was observed by Dr. Herschel, in 1799, computed to be more than fifty thousand miles in diameter. In most of them, there is a very dark nucleus, surrounded by an umbra, or fainter shade. A distinct and well-defined boundary intervenes between the umbra and nucleus. The part of the umbra nearest the dark nucleus is generally brighter than that portion which is more distant.

A spot on the Sun appears at the Earth to perform a revolution round the Sun from west to east in a little more than twenty-seven days, a period longer than the time in which the Sun revolves on its axis. The excess is occasioned by the motion of the Earth in its orbit. The spots on the Sun are generally confined to a zone extending about 35° each way from the solar equator. None have been seen nearer the poles than the solar latitude of $39^{\circ} 5'$.

The Sun rarely appears pure and unsullied by spots. Sometimes, however, none are seen on his disk for several years in succession. From the year 1676 to the year 1684, not a single spot was seen on the Sun.

The light of the Sun is progressive, and not instantaneous, as formerly supposed. It is a little more than eight minutes in coming from the Sun to the Earth. On this account, the Sun and other heavenly bodies appear to the east of their true place. Let S be the Sun, (Plate v. Fig. 4,) A B C the equator, or a parallel of latitude on the Earth. If light were instantaneous, it would be noon at A, when the Sun is on the meridian, as at D. But as light is progressive, a meridian must pass more than two degrees eastward from A to B, after a ray is emitted from the Sun, before it arrives at the Earth. The Sun, when over the meridian at A, must appear at E. The student may think it more truly Copernican to be told, that light, emitted from the Sun

towards a spectator, does not arrive at him, but presents the image of that luminary to inhabitants two degrees to the west of his meridian.

What is the Sun? How is the Sun placed in respect to the planetary orbits? Has the Sun any motion? How often does it turn on its axis? How is it proved that the Sun is globular? What is its diameter? Its circumference? How many times larger than the Earth is the Sun? How long would a celestial courier, passing at the rate of 40 miles in a day, be in circumambulating the Sun? Would 240,000 miles, the distance of the Moon from the Earth, reach from the centre to the circumference of the Sun? What was the ancient opinion respecting the physical construction of the Sun? What must the surface of the Sun resemble? If heat come from the Sun, why is it always cold in the upper regions of the air? Does the height of the most elevated mountain, or of the atmosphere, bear any perceptible proportion to the distance of the Sun from the Earth? According to Dr. Herschel's opinion, are there spots on the Sun? What was Dr. Herschel's hypothesis respecting the Sun? What are openings? What are shallows? What are ridges? What are nodules? What are corrugations? What are indentations? What are pores? What was Dr. Brewster's opinion respecting the physical construction of the Sun? What objection can be made to the theories of Dr. Brewster and Dr. Herschel? What were the opinions of different authors respecting heat or caloric? What objection is there to Mr. Dick's theory? Has the Sun an atmosphere? What is considered its height? By whom were spots first discovered on the Sun? At what time were they discovered? How large spots have been seen? Does the Sun ever appear free from spots? Is the light of the Sun instantaneous? In what time does it come from the Sun to us? Do the heavenly bodies appear in their true place?

SECTION III. *Of the Planets.*

The word *planet* is derived from the Latin *planeta*. This is a derivative from the Greek *planao*, I cause to wander. The Greek primitive *planee*, error, or wandering, is the root, or original word.

From modern discoveries, the primary planets may now be reckoned eleven—Mercury, Venus, the Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Herschel. All these revolve round the Sun in elliptical orbits from west to east, at different distances and in different times. (Plate i. Fig. 3.)

Eighteen secondary planets, or satellites, have been discovered. One revolves round the Earth ; four round Jupiter ; seven round Saturn ; and six round Herschel.

All the primary planets are governed by two great fundamental laws, called, from their discoverer, the great laws of Kepler.

1. If a line be conceived drawn from a planet to the Sun, called a *vector radius*, such a line would pass over equal areas in equal times.

2. The squares of the periodical times are as the cubes of their mean distances from the Sun.

These are established laws "between the rate of motion in any revolving body, whether primary or secondary, and its distance from the central body, about which it revolves." They must, therefore, apply to the satellites in revolving around their primaries.

From what is the word *planet* derived ? What are primary planets ? How many primary planets are there ? What are secondary planets ? How many secondary planets have been discovered ? Which of the primaries have satellites ? How many have each ?

SECTION IV. *Of Mercury.*

Mercury is the planet nearest the Sun. So it is still considered, after the most accurate modern discoveries. It shines by a very brilliant and white light ; but the short period in which it can be viewed, and the position of its body seen through the mists of the horizon, have prevented important discoveries being made on its surface. Of all the planets, Mercury is the most swift in its motion. On this account, the name was given to it by the ancients after "the nimble messenger of the gods." It was "represented by the figure of a youth with wings at his head and feet ; whence is derived ☿, the character by which it is commonly represented." So great is the velocity of this planet, that it performs more than two revolutions to one of Venus, and, commencing at a conjunction, would pass the Earth three times before it would

complete a period, the synodic revolution of Mercury, as seen by us, being 115 d. 21 h. 3 m. 34 s.

The mean diameter of the Sun, as seen from Mercury, is $1^{\circ} 22'$. His mean distance from the Sun is to that of the Earth about as 4 to 10.3. The intensity of the light and heat of the Sun at Mercury must be about as 6.6 to 1 at the Earth, being inversely as the squares of the distances.

The heat of the Sun at Mercury was found by Sir Isaac Newton sufficient to make water boil. Hence beings constituted like the inhabitants of this Earth, cannot endure the climate of Mercury, if Sir Isaac was right, and the degree of heat be in proportion to the proximity of the planet to the Sun. But, from what has been before considered, the circumstances of caloric and atmosphere may be so diversified; they may be so rare at the surface of Mercury, as to render the climate of this planet not only tolerable, but salubrious, a comfortable abode for animal life. This, however, we know, that, with infinite ease, the Deity could form constitutions suited to any situation or climate, destined by him for the creatures of his care.

The surface of Mercury contains nearly thirty-two millions of square miles. It may therefore sustain a population far more numerous than the present inhabitants of the Earth.

According to Dr. Herschel, Mercury is equally luminous in every part of his body, having neither dark spots nor uneven edge, but a disk well defined in every part. Mr. Schroeter, on the contrary, pretends to have discovered in this planet not dark spots only, but mountains. On the authority of the latter observer rests the discovery of a revolution of Mercury on his axis.

ELEMENTS OF MERCURY.

Diameter, 3180 miles.

Mean diameter, as seen from the Sun, $16''$.

Inclination of its orbit to the ecliptic, $7^{\circ} 0' 1''$.

Tropical revolution, 87 d. 23 h. 14 m. 33 s.

Sidereal revolution, 87 d. 23 h. 15 m. 44 s.

Hourly motion in orbit, 110,113 miles.

Place of ascending node, $16^{\circ} 19' 10''$, Taurus.*

Place of descending node, $16^{\circ} 19' 10''$, Scorpio.

Motion of the nodes in longitude for 100 years, $1^{\circ} 12' 10''$.

Retrograde motion of the nodes in 100 years, $11' 22''$.

Place of aphelion, $8s 14^{\circ} 49' 54''$.

Motion of the aphelion in longitude for 100 years, $1^{\circ} 33' 45''$.

Diurnal rotation, according to Schroeter, 24 h. 5 m. 28 s.

Mean distance from the Sun, 37,000,000 miles.

Eccentricity, 7,557,630 miles.

How is Mercury situated? With what light does it shine? Why was it called Mercury? What is the velocity of Mercury compared with that of Venus and the Earth? How much greater is the intensity of the Sun's light and heat at Mercury than at the Earth? What did Sir Isaac Newton find the heat of the Sun at Mercury to be? Can Mercury be habitable? What population may Mercury sustain? How did the disk of Mercury appear to Dr. Herschel? How did it appear to Schroeter?

SECTION V. Of Venus.

Venus is to us among the most brilliant of the luminaries seen in the nocturnal heavens. She appears west of the Sun from her inferior to her superior conjunction, and, rising before him, is called *Phosphor*, *Lucifer*, or the *morning star*. Appearing east of the Sun from her superior to her inferior conjunction, she sets after him, and is called *Hesperus*, *Vesper*, or the *evening star*. She is in rotation east or west of the Sun about 292 days; but, obscured by his light when near that luminary, she is not visible quite so long. It is said, that, before the time of Pythagoras, the morning and evening

* In the elements of the planets, when there is a variation by time, the computation is to the 1st of January, 1831.

stars were supposed to be different, and that he first discovered them to be the same.

The apparent motion of Venus round the Sun is retarded by the motion of the Earth in its orbit, both being in the same direction. Her real revolution is performed in 224 d. 16 h. 49 m. 15 s.; her apparent or *synodic*, in 583 d. 22 h. 7 m. 20 s. She appears, therefore, east or west of the Sun longer than the whole time of a revolution in her orbit.

"Venus is denoted by the character ♀, which is supposed to be a rude representation of a female figure, with a trailing or flowing robe."

Venus must at times present to the inhabitants of Mercury a view far more brilliant than can be enjoyed by us. When at her least distance, she turns to them her whole illuminated side. But when she is nearest to us, her dark side is towards the Earth.

This planet is distant from the Earth, when nearest, about 27,000,000 miles; when most remote, about 163,000,000 miles. "Were the whole of its enlightened surface turned towards the Earth, when it is nearest, it would exhibit a light and brilliancy twenty-five times greater than it generally does, and appear like a small brilliant moon." *Dick's Christian Philosopher*.

The bright side of Venus is turned nearly or quite towards us, at her superior conjunction; but she is then invisible, being near the Sun, or hidden behind his body. When visible, and the illuminated part nearly round before or after that conjunction, she appears small, on account of her great distance.

Venus shines with a light extremely pleasant. Her silver brightness far surpasses that of the Moon, and is unequalled by any of the heavenly luminaries, except sometimes by Jupiter, or by Sirius, the most brilliant of the "starry train." Venus may occasionally be seen in the day time by the naked eye. The obstruction of her morning and evening light frequently causes shadows, well defined, like those of a new moon.

The distance of Venus from the Sun is to that of the

Earth from the Sun about as 7 to 10. The light and heat derived from the solar rays are to the inhabitants of Venus nearly double to those enjoyed by the inhabitants of the Earth.

Dr. Herschel observed spots on Venus. To him she appeared much brighter round her limb than at the intervening line between the enlightened and dark part of her disk. From this he concluded that Venus, like the Earth, had an atmosphere, and that it was more luminous than the body of the planet. The height of this atmosphere, according to the computation of some, is about fifty miles. Such computation, however, ought to be received with great allowance for uncertainty. The surface of the planet being enveloped in her atmosphere, may be the reason that so few spots have been seen on her disk. Plate iii. fig. 1 represents the spots on Venus observed by Bianchini. On the nineteenth of June, 1780, Dr. Herschel observed the spots as represented in fig. 2, where *a d c* is a spot of darkish blue color, and *c e b* a brighter spot. They meet in an angle at the point *c*, about one third of the diameter of Venus from the cusp *a*. Fig. 3 represents the appearance of Venus with her blunt horn and rugged edge.

"Mr. Schroeter," says Dr. Brewster, "seems to have been very successful in his observations upon Venus; but the results which he has obtained are more different than could have been wished from the observations of Dr. Herschel. He discovered several mountains in this planet, and found that, like those of the Moon, they were always highest in the southern hemisphere; their perpendicular heights being nearly as the diameters of their respective planets. From the eleventh of December, 1789, to the eleventh of January, 1790, the southern hemisphere of Venus appeared much blunted with an enlightened mountain, in the dark hemisphere, nearly 22 miles high." He states the result of four mountains measured by him :

First,	22.05 miles.	Third,	11.44 miles.
Second,	18.97 "	Fourth,	10.84 "

The bluntness and sharpness, alternately apparent in the horns of Venus, arise, he supposes, from the shadows of high mountains.

From the changes which appear in her dark spots, and, as inferred by Mr. Schroeter, from the illumination of her cusps when she is near her inferior conjunction, the atmosphere of Venus is considered very dense.

The diameter of Venus has been considered about 220 miles shorter than that of the Earth. But it appears from the measurements of Dr. Herschel, that her apparent mean diameter, reduced to the distance of the Earth, is $18''.79$, that of the Earth being $17''.3$. "This result," says Dr. Brewster, "is rather surprising; but the observations have the appearance of accuracy."

ELEMENTS OF VENUS.

Inclination of her orbit to the ecliptic, $3^{\circ} 23' 32''$.

Diameter, 7,687 miles.*

Mean diameter, as seen from the Sun, $23''.3$.

Tropical revolution, 224 d. 16 h. 46 m. 15 s.

Sidereal revolution, 224 d. 16 h. 49 m. 15 s.

Hourly motion in orbit, 79,226 miles.

Place of ascending node, Gemini, $15^{\circ} 8' 9''$.

Place of descending node, Sagittarius, $15^{\circ} 8' 9''$.

Motion of the nodes in longitude for 100 years, $51' 40''$.

Retrograde motion of the nodes in 100 years, $31' 52''$.

Place of the aphelion, $10^{\circ} 1' 19''$.

Motion of the aphelion in longitude for 100 years, $1^{\circ} 21' 0''$.

Diurnal rotation, 23 h. 20 m. 59 s.

Mean distance from the Sun, 68,000,000 miles.

Eccentricity, 473,100.

When is Venus morning and when evening star? By what names is she called? How long does she appear east or west of the Sun? Who first discovered that the morning and evening stars were the same? Why has Venus this character, Q? How must Venus ap-

* According to Dr. Herschel, 8,648 miles.

pear to the inhabitants of Mercury? Were the whole enlightened side of Venus turned towards us when she is nearest the earth, how would she appear? Is Venus visible in the day time? How do shadows appear in her light? How are the light and heat of the Sun at Venus compared with the same at the Earth? Has Venus an atmosphere? How high did Mr. Schroeter make the mountains of Venus?

SECTION VI. *Of Mercury and Venus.*

Mercury and Venus are both constant attendants on the Sun; in the one part of their course, being the harbingers of the morning; in the other, brightening the veil of evening with their setting splendor. Often seen in conjunction with the Sun, but never in opposition, they form a demonstration of the truth of the Copernican system.

The *inferior* conjunction of Mercury or Venus is, when the planet comes between the Earth and the Sun, or so near the connecting line between them as the obliquity of its orbit will admit. It is, when referred to the ecliptic, in the same longitude with the Sun, though it may be farther north or south. The *superior* conjunction of either of these planets is, when the planet, in that part of its orbit most distant from the Earth, comes into the same longitude with the Sun. It is then either hidden behind the great luminary, or passes by it on the north or south.

Mercury and Venus are called *inferior** planets, because their orbits are nearer the Sun than the orbit of the Earth.

When an inferior planet is at its greatest elongation, a line passing from the Earth through the planet is a tangent to the planet's orbit. The greatest elongation of Mercury is $28^{\circ} 20'$; of Venus, $47^{\circ} 48'$. The orbit of these planets being elliptical, the greatest elongation on

* Objection has been raised against the terms *inferior* and *superior*, as applied to the planets; but the terms, not improper in themselves, are sanctioned by time and the usage of the first European astronomers.

one side of the Sun may not be equal to that on the other side. For the position of the planets at the greatest elongation, see Plate v. Fig. 1, at that part of their orbits where they appear stationary.

Mercury, like Venus, is alternately morning and evening star, though not generally thus known. Like Venus, being west of the Sun from the inferior to the superior conjunction, it rises before him in the morning; from the superior to the inferior, east of the Sun, it sets after him in the evening.

The apparent motion of the inferior planets is greatest at the conjunctions. From the greatest elongation on one side to the greatest elongation on the other, through the superior conjunction, their geocentric motion is direct; through the inferior conjunction, this motion is retrograde. At their greatest elongation, they appear stationary in respect to the Sun. A small part of the orbit nearly coinciding with the tangent line, and the eye of the observer being in that line, the motion of the planet must be either towards such observer or from him, and, of course, must be imperceptible.

Let *S* be the Sun, (Plate v. Fig 1,) *E* the Earth, *M* Mercury, and *V* Venus. When the Earth is at *i*, Mercury in his orbit at *b* appears stationary at *e*. While Mercury is moving from *b* through his superior conjunction at *c* to *d*, his motion appears direct among the fixed stars from *e* to *f*. At *d* his motion is imperceptible for a short time, when he appears stationary at *f*. As he passes from *d* through his inferior conjunction to *b*, his motion appears to be retrograde. At *b* he again appears stationary. The Earth moves round the same focal point with Mercury, and in the same direction from west to east. But Mercury, being much more swift in its motion than the Earth, has a relative velocity. This relative velocity only gives it the appearance of a retrograde motion.

The retrograde motion of Mercury, in regard to the fixed stars, does not commence when the planet is at the greatest elongation east, nor does it continue till the

planet is at the greatest elongation west of the Sun. For at these greatest elongations, the planet will appear to move forward with the same velocity as the Sun appears to advance by the motion of the Earth in its orbit. The stationary appearance, in relation to a fixed star, must be, when the geocentric westerly motion of the planet counterbalances the Sun's apparent easterly motion.

Venus, like Mercury, has her stationary appearance, her direct and retrograde motion. This will appear by a slight inspection of the figure.

The retrograde appearance between the Earth and Mercury is reciprocal. When, at the Earth, Mercury appears to move from *d* to *b*, the Earth must seem to an inhabitant at Mercury to retrograde from *h* to *g*. Hence the superior planets, when in opposition to the Sun, have the appearance of retrograde motion, as seen from the Earth.

The motion of all the planets, as seen from the Sun, is direct. The situation and motion of the Earth causes their stationary or retrograde appearance, when viewed by us.

Mercury and Venus, in their revolutions round the Sun, assume all the phases of the Moon. (Plate iii. Fig. 1, 2, and 3.)

We are told by Ryan, in his Grammar of Astronomy, that "the different phases or appearances of Venus were first discovered by Galileo, in 1611, which fulfilled the prediction of Copernicus, who foretold, before the discovery of the telescope, that the phases of the inferior planets would be one day discovered to be similar to those of the Moon. The accomplishment of this prediction affords some of the strongest and most convincing proofs of the truth of the Copernican system of the world that can be obtained."

One half of each of the planets is illuminated by the Sun. Thus it has been uniformly said by authors. On strict examination, however, it will be seen, that a fraction more than a hemisphere is illumined, the Sun being a much larger body than any of the planets. The en-

lightened side of Mercury and Venus (Plate v. Fig. 1,) are turned from the Earth at their inferior conjunctions. In these conjunctions, when at or very near their nodes, they appear as dark spots passing over the Sun's disk. At other times, invisible to us, they pass the Sun unobserved. They appear nearly full at their superior conjunctions; but never completely so, as their enlightened side is never turned directly towards us, except at the nodes, when they are hidden behind the body of the Sun.

In what respect are Mercury and Venus similar? When is the superior conjunction of these planets? When the inferior conjunction? When does the motion of these planets appear direct? And when retrograde? When do they appear stationary? How is the motion of all the planets as seen from the Sun? Who foretold that Mercury and Venus would assume the phases of the Moon? Who first discovered the different phases of Mercury and Venus? What part of each planet is illuminated by the Sun?

SECTION VII. *Of the Earth.*

Next to Venus, in the solar system, is the Earth. This is the planet by far the most worthy of our attention; though astronomy forbids us fully to adopt the language of the poet:

"Through worlds unnumbered though the God be known,
 'Tis ours to trace him only in our own."

The Earth affords sustenance to innumerable animated beings, which people its surface. It is our habitation in life, and kindly covers our remains when the parting spirit has taken its flight. In its peaceful bosom our dust must slumber, till called forth by "*the voice of the archangel and the trump of God.*"

The Earth is spherical in its form. It is not, however, a complete globe. Elevated at the equator, and flattened at the poles, its form is an oblate spheroid; resembling, in some degree, the well-known English turnip.

Of the rotundity of the Earth any person may satisfy himself. The clouds at a distance appear to rise from

the horizon, or to sink below that circle, which they could not do were the Earth an extended plain. If, in a level country, a person travel north for many miles, he will find, by accurate observation, the north star rising, and discover other stars unseen at his former station. If he go south, these stars will be depressed, and southern stars will rise to his view.

The masts and sails of a ship at sea are seen by a spectator on land, when the hull is hidden behind the convex surface of the water. Were the surface level, the hull, being largest, would first appear.

The outline of the Earth's shadow, seen in partial eclipses of the Moon, is circular. This it could not be, were not the Earth of a spherical form. For, as it presents different sides to the Sun in different eclipses, and even in the same eclipse, the outline of the shadow would be different, in conformity to the original.

The spherical figure of the Earth is placed beyond all doubt by its having been many times circumnavigated.*

The true form of the Earth, its *spheroidical figure*, was first discovered by the pendulum, a longer line being required to vibrate seconds towards the poles than at the equator. Some diversity in the proportion of the diameters is found in different authors. This is not wonderful in a case requiring so much nicety of observation. The excess of the equatorial diameter over the polar has been stated at 24, 34, and 37 miles. In Rees's Cy-

* The first who sailed round the globe was the crew of Ferdinand Magellan, a Portuguese in the service of Charles V. of Spain. He left Seville, Aug. 10, 1519, discovered and passed the straits having his name. After crossing the Pacific ocean, he was slain in a rash encounter with the natives at Matan, one of the Philippine islands. His ship returned by the Cape of Good Hope, Sept. 8, 1522.

Sir Francis Drake sailed from Plymouth, Eng. Dec. 13, 1577, passed round the globe westward, and returned Nov. 3, 1580.

The circumnavigation was next performed by Sir Thomas Cavendish. After him North, or Noort, Anson, Cook, and many others, circumnavigated the globe. A voyage round the world is now become so common as scarcely to attract notice.

clopedia, the equatorial diameter is reckoned at 7977, the polar at 7940, considered by the author but "an approximation to a true estimation." In the Practical Navigator of Dr. Bowditch, the diameter is considered 7964. Thus the mean diameter will be considered in this compend.

The errors of antiquity, of childhood, and ignorance, in considering the Earth an extended plain, or unbounded in its dimensions, are corrected by philosophy. Its true form is now well known to the scientific world. But the astronomical student is in danger of verging to the opposite extreme. When he considers the Earth as a planet, greatly inferior in magnitude to several wandering orbs of his own solar system; immensely less than the Sun; and the Sun but a speck in the Creator's works,—he seems to contract its true dimensions, and to be insensible, that still, to its inhabitants, it is a globe of vast magnitude; of which and its kindred orbs it may be truly said, "these little things are great to little man." Considering the diameter of the Earth 7964 miles, the circumference is about 25,020 miles, and the superficial contents, or surface, 199,259,280 square miles.

If a person were so elevated that he could see twenty miles in every direction, his prospect would include a region of more than 1256 square miles. Should he survey a new region of this extent every day, he would not pass over the whole of the Earth's surface under 434 years. Thus the life of an antediluvian would be necessary for such a survey.

Were a being of sufficient longevity and suitably constituted to undertake an examination of the Earth's surface by traversing every square mile, and were he to proceed with such rapidity as to inspect a mile an hour, or twelve miles in the light of every day, he would find himself far short of his purpose at the end of 45,000 years.

Six great circles are conceived drawn round the Earth; the *equator*, *ecliptic*, *meridian*, *horizon*, and two *colures*.

The *equator* is an imaginary circle encompassing the Earth from east to west ; the plane of the circle dividing it into northern and southern hemispheres.

The *ecliptic* is a great circle, in which the Earth performs its annual revolution ; or in which the Sun appears to perform an annual revolution round the Earth. It is divided into twelve equal parts, denominated the twelve signs of the ecliptic, each containing 30° ; Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.

The plane of the equator is inclined to the ecliptic in an angle of about $23^{\circ} 28'$. (See *Obliquity*.)

The *meridian* is a great circle encompassing the Earth from north to south, passing through the poles, and crossing the equator at right angles. It is represented on an artificial globe by a graduated circle of brass. It is called *meridian*, from the Latin word *meridies*, mid-day, because, when it arrives at the Sun, the time is noon, or the middle of the day.* As many meridians may be conceived as there are places east or west of each other ; but all places directly north or south of each other have the same meridian.

The *horizon* is a great circle surrounding the Earth, ninety degrees distant from the zenith and nadir of any place. The plane of this circle, passing through the centre of the Earth, divides it into upper and lower hemispheres. This is called the *real* or *rational horizon*. The *sensible horizon* is the circle which limits our view, dividing the visible part of the heavens from the invisible. The horizon is represented on an artificial globe by a circle of wood having several other circles drawn upon its surface.

The *colures* are meridians ; but meridians particularly distinguished. The *equinoctial colure* is a line drawn round the Earth from north to south through the equinoctial points Aries and Libra. The *solstitial colure* is a line drawn round the Earth in the same di-

* Half of this circle is usually called a meridian.

rection; but through the solstitial points Cancer and Capricorn.

There are four less circles represented on an artificial globe, and considered circles of the Earth; *two tropics* and *two polar circles*. They are drawn parallel to the equator. The northern tropic, called the tropic of *Cancer*, encompasses the Earth at about $23^{\circ} 28'$ north of the equator; the southern, called the tropic of *Capricorn*, at the same distance south of the equator.

The polar circles are drawn round the Earth at about $23^{\circ} 28'$ from the poles. The northern is called the *Arctic*, the southern the *Antarctic* circle.

Latitude is the distance from the equator north or south. It is reckoned in degrees,* minutes, and seconds. Lines of latitude are drawn on a terrestrial globe, on each side of the equator, and parallel to that circle. They are called *parallels of latitude*. These are considered circles of the Earth, and are at stated distances from the equator to the poles. They may, however, be conceived to be drawn at any distance from each other, or from the equinoctial, every place, north or south, having its own parallel.

Longitude is the distance east or west from some fixed meridian. This also is reckoned in degrees and sexagesimal parts of a degree. It increases each way from the meridian; 180° , or half way round the globe, being the highest longitude. (See article *Longitude*.)

The Earth is embraced by five zones; the *torrid*, *two temperate*, and *two frigid*. The torrid zone (Plate v. Fig. 6,) extends from the equator each way to the tropics; the temperate zones include the whole space from the tropics to the polar circles; and the frigid zones the remaining space from the polar circles to the poles.

The division of the Earth's surface into zones is not

* Every circle, large or small, is divided into 360° . A degree on the surface of the Earth is the 360th part of its circumference. The centre of this circle must be at the centre of the Earth. See a *terrestrial artificial globe*.

imaginary, but has a foundation in nature. The *torrid zone* comprehends all that region where the Sun is vertical at any season of the year. The *temperate zones* spread over the whole of the Earth's surface from the tropics to the extreme limit of continual and successive day and night, the Arctic and the Antarctic circles being drawn at the bound, where the longest day is 24 hours. At that bound the Sun does not appear to set at the summer solstice, nor to rise at the winter solstice.

The *frigid zones* are enveloped in light and darkness in alternate succession. The Sun, at its greatest declination north, shines over the north pole to the Arctic circle. The whole northern frigid zone is then illuminated, and, by the diurnal motion of the Earth, revolves wholly in the light. The southern frigid zone, precluded from the Sun's rays, is then involved in entire darkness. When the Sun is in his greatest declination south, shining over the south pole to the Antarctic circle, the southern frigid zone is enlightened; the northern, abandoned by the Sun, is shrouded in darkness. The continuance of light or darkness in the Arctic and Antarctic regions is longer, the nearer any place is to either pole, where the day and the night continue alternately for six months; except the greater prevalence of light from refraction and other causes.

The Earth has three motions; its diurnal rotation on its axis; its annual motion in its orbit round the Sun; and the revolution of its axis round the poles of the ecliptic.

The rotation of the Earth on its axis is performed in 23 h. 56 m. 4 s. or one sidereal day. This is a most uniform motion. By bringing the different parts of the Earth to the Sun in succession, it produces day and night. Given to this Earth, at its creation, by an all-benevolent Creator, it continues a constant return of blessings to his dependent creatures. This motion is from west to east. It causes the apparent revolution of the heavenly bodies in a contrary direction, from east to west.

Different parts of the Earth, in this rotation, move with unequal velocity. Greatest at the equator, it decreases towards the poles, as the cosines of the latitude decrease. A place in Borneo or the Colombian republic, at the equator, moves about 1042 miles an hour; Washington city, 811 miles; Boston, 770 miles; London, 649 miles; St. Petersburg, 522 miles; an inhabitant of Greenland, in latitude 80° , only 181 miles. When this motion is on the side of the Earth opposite the Sun, it nearly coincides with the immense velocity of the Earth in its orbit. By this motion the centrifugal force of an object near the equator is greater than at any parallel of latitude. This, as well as its distance from the centre of gravity, causes objects to be lighter at the equator than near the poles. The farmer and mechanic know, that the water on a grindstone, turned swiftly round, rises towards the highest part, and flies off by increased velocity. A similar effect would be produced on the Earth, were the motion sufficiently increased. "If," says Dr. Enfield, "the diurnal motion of the Earth round its axis was about 17 times faster than it is, the centrifugal force would, at the equator, be equal to the power of gravity, and all bodies there would entirely lose their weight. But if the Earth revolved still quicker than this, they would all fly off."

The circles, which the heavenly bodies appear to describe by this motion of the Earth on its axis, assume a different position as seen from different parts of the Earth's surface; the great concave of the heavens, or *celestial sphere*, changing its appearance, as differently viewed by the spectator.

At the equator, the inhabitants have a *right sphere*, all the heavenly bodies appearing to rise and set at right angles to the horizon. The celestial equator passes through the zenith and nadir. The poles are in the horizon.

From the equator to the poles, the inhabitants have an *oblique sphere*. The apparent circles, or circles formed by the apparent motion of the heavenly bodies, are

oblique to the horizon ; but forming angles with it less as they are farther from the equator ; till, at the poles, they become parallel to the horizon, or coincide with that circle. To a person passing from the equator towards either pole, the pole-star of his hemisphere appears to rise, and, at a distance from the equator, the stars, the same distance from his elevated celestial pole, do not set ; but appear to revolve in circles greater as they are farther distant from the pole.

At either pole, a person would be presented with a *parallel sphere* ; all the visible stars, the pole-star excepted,* would appear to revolve in circles parallel to the horizon. The Sun, also the Moon, and other planets, would seem to revolve in circles very nearly parallel to the horizon. When first appearing in view, they would seem to skim the horizon round. Ascending gradually by spiral circles and by scarcely perceptible advances, they would move to their extreme altitude. The greatest elevation of the Sun at this time, 1831, would be $23^{\circ} 27' 38''$; of the Moon at times, $28^{\circ} 36' 41''$. Mercury and some of the asteroids would rise still higher. They would descend by the same gradual spiral movement, till they again sink below the horizon.

The orbit of the Earth is formed by its annual motion round the Sun. It is an ellipse, with the Sun in one of the foci. The Sun and Earth always appear in opposite signs, the apparent motion of the Sun in the ecliptic being caused by the revolution of the Earth in its orbit.

The irregularity of the Earth's motion in its orbit was unknown to the ancients till the time of Hipparchus. About one hundred forty years before the Christian era, he first discovered that this motion was not uniform. Succeeding astronomers, long perplexed, invented many cycles and epicycles to explain the observed irregularity. It remained, however, a mystery till the true cause was discovered by Kepler. He assigned to the orbit its

* The northern pole-star, not being exactly at the pole, would appear to make a very small circuit. (See article *Longitude*.)

true elliptical figure, and ascertained that the annual motion of the Earth was subject to the curious law, before named, as subsisting between the planets and their principal; that if a line be drawn from the Earth to the Sun, (Plate vi. Fig. 1,) such a line would pass over equal areas in equal times; so that the nearer the Earth is to the Sun, the swifter is its motion; and the farther it is distant, the slower is its motion.

The Earth's axis, in different parts of its orbit, has nearly a similar position; for, if straight lines be drawn, representing this position in different points, such lines would be parallel to each other, except the very small variation arising from the precession of the equinoxes. The axis is not perpendicular to the plane of the Earth's orbit, but is inclined to a perpendicular line, in an angle of about $23^{\circ} 28'$; or it is inclined to the plane of the orbit in an angle of about $66^{\circ} 32'$. From the parallel position of the axis and its inclination, important effects are produced upon the Earth's surface. For to this parallel position and inclination we are indebted for the inequality of day and night, and the variety of seasons. A fit representation may be made of these by a common terrestrial globe. Let a candle be suspended in the middle of a large room or hall, a few feet from the floor; let the globe, taken from the frame, be holden east of the candle on a level with it, the north pole so elevated that the axis may form an angle with the floor of about $23^{\circ} 28'$; but perpendicular to a line drawn from the candle, or the poles equally distant from the candle. In this position very nearly one half of the globe will be illuminated. Thus situated, let the globe be turned gently round from west to east. Every part of the surface will pass through light and darkness in nearly equal proportions. (Plate vi. Fig. 2, Spring.) This will represent the situation of the Earth at the time of the vernal equinox, when the regions near the poles, like those at the equator, have their days and nights very nearly equal. With the axis parallel to its former position, let the globe be held under

the candle, and turned round as before. This will represent the Earth at the time of the summer solstice. (Plate v. Fig. 2, Summer.) The Arctic regions, or the whole northern frigid zone, will be in the light; the Antarctic regions, or the southern frigid zone, in darkness. From the Arctic circle to the equator, every part will have more light than darkness, and proportionally more as nearer to the circle, or farther distant from the equator. Every part south of the equator to the polar circle will have more darkness than light, and proportionally more as farther distant from the equator, or nearer to the Antarctic circle. The whole region from this circle to the south pole will be in entire darkness. A western position, or the globe placed west of the candle, will represent the situation of the Earth at the time of the autumnal equinox, the days and nights again equal over the whole Earth. (Plate vi. Fig. 2, Autumn.) Placed directly over the candle, the globe will exemplify the winter solstice, with the short days and long nights of the northern hemisphere, and the long days and short nights of the southern hemisphere. (Plate vi. Fig. 2, Winter.) It will be perceived that the candle, being less than the globe, shines over a fraction less than one half of it; while the Sun, being much larger than the Earth, must illumine a fraction more than one half of its surface. These differences are too small to affect the representation. It has been usual, in representing the seasons by a diagram, to draw an ellipse for the Earth's orbit, and to place the figure of the Earth in different positions. In most of these, no consistent view is given of spring and autumn. In all, so great stretch of imagination is required, that it was thought advisable to omit the ellipse in this Compendium, and give a simple view of the Earth as illuminated by the Sun at the different seasons. Let the student extend his views from the globe and the candle to the Earth and the Sun, and he may have some adequate conception of the cause of inequality in the length of days and nights, and the variety of seasons. To form

extended views of the great objects of the heavens, diagrams, and globes, and orreries, may be of great use ; but care must be taken, that the mind be not confined to these auxiliaries ; otherwise, instead of being helps, they may lead to embarrassment.

The Earth makes a complete revolution round the Sun, or from a star to the same star again, in 365 days 6 h. 9 m. 12 s. This is called the *sidereal year*. From an equinox or a solstice to the same again, it revolves in 365 d. 5 h. 48 m. 51 s. 36 ds. This is usually called the *tropical year* ; but sometimes the *equinoctial or solstitial year*. It is usually reckoned from the first degree of Aries, but may be computed from any other point of the ecliptic. The Earth performs a revolution, from the aphelion of its orbit to the same again, in 365 d. 6 h. 14 m. 2 s. This is denominated the *anomalistic year*.

On account of the elliptical form of the Earth's orbit, the Sun being in one of the foci ; and on account of the present place of the aphelion, the Earth is between seven and eight days longer in passing the six northern signs than the six southern. Comparing the time from the vernal equinox to the autumnal with that from the autumnal to the vernal, will make this apparent. The inhabitants of the northern hemisphere, by this inequality, enjoy a greater share of the Sun's influence than the southern ; or the northern enjoy this influence for a longer time. It would seem, however, that the southern inhabitants must have the most intense tropical Sun, as their summer is at the time when the Sun is nearest the Earth.

The aphelion of the Earth's orbit moves forward 1' 2" in longitude, 11".882 in absolute space, in a year. Hence it passes from a point in the ecliptic to the same again in 20,903 years. But a complete revolution from a star to the same star again requires about 110,000 years. Considering the time of the creation, according to the received opinion from the Mosaic account, 4004 years before the Christian era, it must have been about

the time when the northern and southern hemispheres enjoyed summers and winters of equal length, the earth being in the aphelion of its orbit about the time of the vernal equinox. Probably the equality was at the very time of the creation ; and the slight variation, which now appears, arises from a want of complete accuracy in the ancient computation of time ; or from the great difficulty of ascertaining the exact motion of the aphelion, in which authors are not perfectly agreed.*

The aphelion moving forward increased the length of northern summer. The ascendancy thus gained in the northern hemisphere continued to increase till about the year 1255. From that time to the present, the length of northern summers has decreased, and will continue to decrease till about the year 6481, when the summers in the different hemispheres will again become equal. After that, the southern will have the superiority, or the longest continuance of the Sun's influence, for more than 10,000 years.

The Earth, in the aphelion of its orbit, is more than 3,000,000 miles farther from the Sun than it is in the perihelion. It is in the aphelion on the second day of July the present year, 1831 ; though, on account of bissextile, it will be in that point on the first of July in the next year, 1832. It has generally been in the aphelion on the first day of July, and in the perihelion on the last day of December, since the commencement of the present century. In the latter part of the century, it will be in the aphelion on the second day of July ; in the perihelion on the last day of December in some years, on the first day of January in other years, varying on account of bissextile. No doubt the whole earth is warmer at the time of winter than at the time of summer, in the

* Though the sacred writings stand in no need of auxiliaries ; and though perfect reliance should not be placed on astronomical calculations, as proof of Scripture chronology ; yet the circumstance of equality of seasons, at the time the Earth commenced its being and revolutions, must be considered a forcible corroboration of the Mosaic account.

northern hemisphere. But at the time of our winter, the rays of the Sun fall obliquely ; in high latitudes, very obliquely in winter. Of course a much less number light upon any given space, as a square mile, or any number of square miles, than when they fall directly upon such space. (Plate v. Fig. 6.) The short continuance of the Sun above the horizon in the contracted days of winter, does not give time for the heat to accumulate, while the long days of summer give opportunity for redoubled force. It may be added, that 3,000,000 miles, though a vast distance, are very small in proportion to the immense distance of the Sun.

Spring and summer to us are coincident with autumn and winter to the inhabitants of the southern hemisphere ; autumn and winter to us, with spring and summer to such inhabitants.

The mean distance of the Earth from the Sun has been found to be about 95,000,000 miles.* This was ascertained by observations made on the transit of Venus, in the year 1761. Prior to these observations, the distance was considered much less. But their accuracy, confirmed by those on the transit of 1769, seems now to command the full assent of the philosophic world. Taking the distance as now reckoned, it makes the diameter of the Earth's orbit 190,000,000 miles, and the circumference 569,902,100 miles, about equal to the elliptical orbit. The Earth, moving this immense distance in a year, must travel more than 68,000 miles every hour. All the inhabitants of the Earth are carried at this inconceivable velocity, 140 times greater than that of a cannon ball, in their perpetual movement round the Sun. Even this velocity is increased, on a part of each day, by the

* We can form but very inadequate ideas of the immense distance of the planets from the Sun. Could a celestial courier travel the expanse of heaven at the rate of 40 miles in a day, he would not be able to pass from the Earth to the Sun in 6,500 years. Had he commenced such a journey at the creation, he would yet be far short of its completion, and must spend hundreds of years more before his arrival at that luminary.

motion of the Earth on its axis. It may shock the credulity of those who are unaccustomed to philosophical observation, that a motion of such velocity should be imperceptible. But we must take notice, that terrestrial objects around the observer, even the atmosphere, move with him in the same direction ; so that with the heavenly bodies only can he compare his motion. By observation on those bodies, the motion of the Earth is ascertained beyond the slightest doubt of the astronomical student. But this motion, if wonderful, is not altogether singular. The passing of a vessel on still water is imperceptible, except from meeting the air, and the apparent motion backward of surrounding objects, till it strikes the shore or other obstruction. No motion on the stillest water is so uniform and even as that of the Earth in its orbit.

The retrograde motion of the axis of the Earth round the poles of the ecliptic causes the difference between the tropical and sidereal years. The equinoxes are annually carried backward, from east to west, $50''.118$ in a year. Thus, in every year, they meet the Sun 20 minutes 24.4 seconds before the Earth arrives at the point in the heavens whence it started at the commencement of the year. This retrograde motion is called *the precession of the equinoxes*. With the equinoctial points move all the signs of the ecliptic. "It follows, that those stars which, in the infancy of astronomy, were in Aries, are now in Taurus ; those of Taurus in Gemini. Hence, likewise, it is, that the stars, which rose or set, at any particular season of the year, in the times of Hesiod, Eudoxus, Virgil, or Pliny, by no means answer at this time, to their descriptions." An example of the change may be seen on our celestial globes. The constellations are placed 30° from the signs to which they originally belonged. This change of place shows the motion of the equinoxes for 2,154 years. A complete revolution of the signs requires a period of 25,858 years. Hence the pole star, or *the north pole*, as it is called, will not

always be the point to which the pole of the Earth will be directed ; but in something more than 12,000 years, will be about 47° from the pole of the Earth, and, when on the meridian, will be in the zenith of some parts of New England.

How should the contemplation of these celestial motions and long periods constrain us to improve the short, fleeting moments of time assigned to us ; and lead us to admire and adore the wisdom and power of Him who formed and still governs the universe with infinite ease ; to whom *'a thousand years are as one day !'*

Why is the Earth more worthy of our attention than the other planets ? What is the form of the Earth ? How may any person satisfy himself of the Earth's rotundity ? Who first circumnavigated the Earth ? Who next ? How was the true form of the Earth discovered ? What is the mean diameter of the Earth ? What is the difference between the equatorial and polar diameters of the Earth ? What is the Earth's circumference ? What its superficial contents ? How many great circles are considered encompassing the Earth ? What are they ? How do you describe each ? What are the smaller circles ? What is latitude ? What is longitude ? Into how many zones is the surface of the Earth divided ? How many motions has the Earth ? In what time does the Earth turn on its axis ? In the rotation of the Earth on its axis do different parts of its surface move with equal velocity ? Where are objects lightest, at the equator or at the poles ? How do the heavenly bodies appear to rise and set in a direct sphere ? How in an oblique sphere ? How in a parallel sphere ? How high can the Sun appear at the poles ? How high the Moon ? How is the Earth's orbit formed ? What is it ? Were the ancients acquainted with the true form of the Earth's orbit ? Who first assigned to the orbit its true elliptical figure ? What is the inclination of the Earth's axis to the plane of its orbit ? To what are we indebted for the inequality of the days and nights, and the variety of the seasons ? How may a fit representation of these be made ? In what do a candle and a globe fail in giving an exact representation of the Sun and Earth ? How long is a sidereal year ? How long is a tropical ? How long is an anomalistic year ? Why is the Earth longer in passing the six northern signs than the six southern ? How much longer is it ? How far forward does the aphelion of the Earth move in a year ? In what time does it complete a revolution ? When did the northern and southern hemispheres enjoy equal lengths of summers and winters ? What may corroborate the Mosaic account of the creation ? When will the seasons in different hemispheres again become equal ? How much farther from the Sun is the Earth in the aphelion than in the perihelion of its orbit ? At what time of the year is the Earth in the

aphelion, and at what time in the perihelion of its orbit? Why have we not warmer weather in winter than in summer? In spring and summer to us, what seasons have the inhabitants of the southern hemisphere? How far is the Sun distant from the Earth? At the rate of 40 miles a day, how long would a celestial courier be in travelling from the Earth to the Sun? What is the diameter and what the circumference of the Earth's orbit? How far must the Earth move in an hour? Why is a motion of such velocity imperceptible? What causes the difference between the tropical and sidereal year? At what rate are the equinoxes carried backward? What is meant by the precession of the equinoxes? Why are the stars on a celestial globe placed differently from their ancient situation? In what time do the signs of the ecliptic perform a complete revolution? Where will the north pole star appear 12,000 years hence?

SECTION VIII. *The Moon.*

The Earth has one satellite, the Moon. This constant attendant is distant from the Earth (240,000) miles.* The Moon, though inferior to most of the heavenly bodies, next to the Sun, is to us by far the most interesting. (By dispelling the gloom of night, she is the solace of the weary traveller) and by constantly changing her countenance, she gives variety and beauty to the nightly canopy.

The Moon performs a revolution round the Earth, from a point in the ecliptic to the same again, in (27 d. 7 h. 43 m. 5 s.) from a star to the same again, in (27 d. 7 h. 43 m. 12 s.) It revolves from the Sun to the Sun again in 29 d. 12 h. 44 m. 3 s. This is called a *mean lunation*, and is a synodical revolution. The Moon always presents the same face to the Earth. Hence in the same time that it performs a revolution, it must revolve on its axis; unless the different sides of the Moon present the same prospect. That there should be a uniformity of appearance in the different sides of the Moon seems very improbable. Astronomers seem agreed in the coincidence of its revolutions; or that it revolves on its axis in the same time that it performs a revolution

* This is its mean distance.

round the Earth. If this opinion be correct, it must be considered, that the side of the Moon next to the Earth is composed of matter more dense than that of the opposite side; and that the powerful attraction of the Earth causes it to revolve on its axis.

Several authors have asserted, that the Moon performs a revolution in $(29\frac{1}{2}$ days), and, in immediate connection, that it turns on its axis in the same time that it performs a revolution. The latter assertion is true; but it is in the time of the sidereal revolution, 27 d. 7 h. 43 m. 12 s. and not in the synodical, or a lunation, about $29\frac{1}{2}$ days, as will appear by an inspection of Plate v. Fig. 2. Let E be the Earth; A B C D the Moon's orbit; *a* a mountain on the side of the Moon next to the Earth. As the Moon passes in her orbit from A to B, 90° , it is evident she must turn on her axis 90° , in order that the same side may be towards the Earth: the mountain will then be at *b*. When the Moon is at C, having passed 180° , half her revolution, the mountain must be at *c*. The Moon at D presents the mountain at *d*. When the Moon returns to A, the mountain must come round to *a* again. Thus, in a sidereal revolution, 27 d. 7 h. 43 m. 12 s. the Moon must have revolved once on its axis, or the same side cannot be presented to the Earth. Dr. Brewster must have been strangely inattentive, when he went into the common error respecting the time of the Moon's revolution on its axis.

The diameter of the Moon is 2,180 miles; But it can be but 2,173 miles, if its apparent diameter be $31' 8''$, as stated by De la Lande.

(The Earth must appear like a moon to the lunarians; but thirteen times as large as the Moon does to us. It must exhibit all the phases of the Moon, but at opposite times. When the Moon appears new to us, the Earth must be full to them; and when the Moon is full to us, the Earth must be new to them.

It is remarkable, that one hemisphere of the Moon enjoys continued light, the Earth, in the absence of the

Sun, being a bright moon to its inhabitants. The other hemisphere has alternate light and darkness in succession, each continuing about $14\frac{1}{2}$ days.

The Moon, like the other planets, is opaque, shining only by the reflected light of the Sun. The side of the Moon which is next to the Sun is enlightened, the other half dark and invisible. Hence, when she comes between us and the Sun, she is not seen, her dark side being then towards us.

When she is advanced a little way in her orbit, a small part of her illuminated side becomes visible in the form of a beautiful luminous crescent. This is called the *new Moon*. When she has performed one fourth of a lunation, her illuminated side becomes dichotomized, or one half of the bright side becomes visible. She is then said to be in her *first quarter*. From this time to her opposition, she is said to be *gibbous*, presenting still more of her illuminated side, as she moves forward, or becoming more protuberant. When she becomes opposite to the Sun, nearly the whole of her enlightened hemisphere is presented to the Earth. She is then said to be *full*; and is called the *full Moon*. It must be remembered, however, that the bright side of the Moon is never exactly towards us, as she is never directly opposite to the Sun; except in her nodes, when she falls into the Earth's shadow, and is eclipsed. From the full to the change, the Moon passes in a retrograde order through the same phases; first gibbous, then dichotomized in her *last quarter*, then horned, till, coming between the Earth and the Sun, she again becomes invisible.

Let S be the Sun, (Plate v. Fig. 3) E the Earth; A B C D E F G H the Moon's orbit; the small circle at these letters, the Moon in different parts of a lunation. The varied appearances of the Moon at the Earth are represented in the external circle at *a b c d e f g h*. To understand these requires but a slight inspection.

The axis of the Moon being almost perpendicular to

the ecliptic, difference of seasons must be nearly unknown to the lunarians.

It is confidently asserted by some astronomers, that there is no lunar atmosphere of any visible density. If so, it must be uninhabitable to beings constituted like the inhabitants of this Earth. It can have neither winds nor clouds, dews nor rains. But all are not agreed in this opinion. "It is not determined," says Enfield, "whether there is an atmosphere belonging to the Moon." But it can hardly be supposed that so large a field remains untenanted. There seems now a strong preponderance in favor of the opinion, that the Moon is surrounded by an atmosphere. "No large seas or tracts of water have been observed in the Moon by Dr. Herschel, or any other astronomer; nor did he notice any indications of a lunar atmosphere. Recent observations, however, on the occultations of Jupiter and Venus by the Moon, render it highly probable, that the Moon, as well as the Earth, is surrounded by an atmosphere. On April 5th, 1824, Mr. Ramage of Aberdeen, Capt. Ross of the navy, and Mr. Camfield, at Northampton, observed, with excellent telescopes, the occultation of Jupiter, and to all of them the disk of the planet appeared distorted, when it approached the limb of the Moon; and Mr. Camfield, at Clapham, on October 30th, 1825, observed on the emersion of Saturn from behind the dark limb of the Moon, first the disk of the planet, and then the eastern extremity of the ring decidedly flattened; a phenomenon perfectly analogous to what would be produced by refraction, and therefore rendering it highly probable, that the Moon is surrounded by an atmosphere." *Guy's Astronomy.*

The dark parts of the Moon attract the attention of the most careless observer. Hence "*the man in the Moon*," is familiar to boyhood, and common to the unlearned. These dark parts were formerly thought to be seas, but are now considered dark cavities, not reflecting the light of the Sun. Many pits and caverns are dark

on the side next to the Sun, which shows that they are hollow. But deep cavities are not all: the surface of the Moon is found to be diversified with large tracts of mountains, (Plate iv. Fig. 2). Dr. Brewster, in his supplement to Ferguson, has well described the irregularities in the lunar surface.

“The strata of mountains and the insulated hills, which mark the disk of this luminary, have evidently no analogy with those in our own globe. Her mountainous scenery, however, bears a stronger resemblance to the towering sublimity and terrific ruggedness of the Alpine regions, than to the tamer inequalities of less elevated countries. Huge masses of rock rise at once from the plains, and raise their peaked summits to an immense height in the air, while projecting crags spring from their rugged flanks, and, threatening the valleys below, seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences are strewn numerous loose and unconnected fragments, which time seems to have detached from their parent mass; and when we examine the rents and ravines, which accompany the ever-changing cliffs, we expect every moment that they are to be torn from their bases, and that the process of destructive separation, which we had only contemplated in its effects, is about to be exhibited before us in tremendous reality. The strata of lunar mountains, called the Apennines, which traverse a portion of her disk from north-east to south-west, rise, with a precipitous and craggy front, from the level of the Mare Imbrium. In some places, their perpendicular elevation is above four miles; and, though they often descend to a much lower level, they present an inaccessible barrier to the north-east, while in the south-west, they sink in gentle declivity to the plains.

The analogy between the surface of the Earth and Moon fails in a still more remarkable degree, when we examine the circular cavities which appear in every part of her disk. Some of these immense caverns are nearly

four miles deep, and forty in diameter. A high, regular ridge, marked with lofty peaks and little cavities, generally encircles them; an insulated mountain frequently rises in their centre, and sometimes they contain smaller cavities of the same nature with themselves. These hollows are most numerous in the south-west part of the Moon; and from this cause that portion of this luminary is more brilliant than any other part of her disk. The mountainous ridges which encircle the cavities, reflect the greatest quantity of light; and, from their lying in every possible direction, they appear, near the time of full Moon, like a number of brilliant radiations, issuing from the large spot called Tycho.

It is difficult to explain, with any degree of probability, the formation of these immense cavities; but we cannot help thinking, that our Earth would assume the same figure, if all the seas and lakes were removed; and it is therefore probable, that the lunar cavities are intended for the reception of water; or that they are the beds of lakes and seas, which have formerly existed in that luminary.* The circumstance of there being no water in the Moon is a strong confirmation of this theory. The deep caverns, and the broken, irregular ground, which appear in almost every part of the Moon's surface, have induced several astronomers to believe that these inequalities are of volcanic origin."

The irregularities of the Moon's surface are of great use to us, by reflecting the rays of the Sun in different directions. If the surface of the Moon were covered with water, or smooth and polished like a mirror, it would reflect the rays of the Sun, but not in the copious manner they are now diffused. In the direction of a reflected ray, she would show the Sun's image not larger than a point, but with a lustre hurtful to the organs of vision.

* The learned author has not told us what has become of the water. Chemists say, bodies are never annihilated.

The light of the Moon is exceedingly soft and cheering ; but is little in the extreme compared with that of the Sun. In this authors are agreed. But, from their different modes of computation, they have come to different results, and made considerable difference in the disproportion between the lunar and solar light. Dr. Hooke, accounting for the reason why the Moon's light affords no perceptible heat, observes, " that the quantity of light which falls on the hemisphere of the full Moon, is rarified into a sphere 288 times greater in diameter than the Moon, before it arrives at us ; and, consequently, that the Moon's light is 104,368 times weaker than that of the Sun. It would therefore require 104,368 full Moons to give a light and heat equal to that of the Sun at noon. The light of the Moon, condensed by the best mirror, produces no sensible heat upon the thermometer.

Dr. Smith has endeavored to show, in his book on optics, that the light of the full Moon is but equal to a 90,900 part of the common light of the day, when the Sun is hidden by a cloud." *Rees's Cyclopadia*.

To a spectator at the Sun, the Moon never appears more than 10' distant from the Earth.

The Moon's orbit is an ellipse, the Earth being in one of the foci. (The point of the orbit nearest the Earth is called the *perigee* ; that farthest distant, the *apogee*.) *Syzygy* is a common name for the conjunction and opposition, or change and full, of the Moon.)

Dr. Herschel saw, or thought he saw (three volcanoes) at the same time in the Moon ; one showing an eruption of fire, or luminous matter ; the other two about to break out, or nearly extinct.

When the Moon is about three or four days old, the part of her disk not enlightened by the Sun becomes visible, faintly illuminated by light reflected from the Earth. The horns of the enlightened part, appearing to project beyond the old Moon, seem part of a sphere larger than the faintly enlightened part. This phenomenon is call-

ed by the unlearned, with much expression, *the old Moon in the new Moon's arms*. Probably it is an optical illusion. Any object bright appears larger than when dark, or faintly illuminated. View from a distance a house painted partly white, the remainder unpainted or dark. The bright part will appear to rise above the unpainted or dark part.

It is a singular phenomenon, that the Sun or Moon near the horizon, appears larger than when seen in the meridian. It is the more singular, as the disk of either, particularly the Moon, must, by calculation, subtend at the Earth an angle increasing with the height of the luminary. To an observer on the Earth's surface, the Sun or Moon must be about 4000 miles nearer at the zenith than at the horizon. The principle is corroborated by actual admeasurement. When subjected to this, either luminary appears largest on the meridian. The apparent increase of magnitude at the horizon must be an illusion of the observer's sight. Objects at a distance appear smaller or larger as our imagination assigns them a situation more or less remote. Without doubt, the difference in appearance must be affected by the medium of vision. Objects often appear magnified in a mist or fog; and, in the dusk of the evening, a small cottage has been mistaken for a distant church. Near the horizon, our vision is rendered more or less obscure by water and other particles floating in the atmosphere. But the view of remote objects may be most affected by the intervention of other objects. Bodies on the opposite side of a plain, a wide-spread meadow, or lake, appear small, because, by the imagination, they are placed at a distance far less than the reality. A ball or vane on the top of a lofty spire appears far less than the same object at an equal distance on the ground. But the error of vision seems corrected by intervening objects, which make us conceive those beyond at a greater distance.

Let the principle be applied to the Sun or Moon,

seen on the meridian or at the horizon. No objects intervene between us and the meridian luminary. Imagination, therefore, places it near the observer. But, at the horizon, a distant hamlet or village, hill, mountain, or other object, seems to throw back the heavenly body, and, making it seem at a greater distance, enlarges its apparent magnitude.

The uniformity of the Moon's visage, or its exhibiting always the same face, is subject to some alteration. Spots on the east and the west, on the north and the south of the Moon, appear and disappear in rotation. The phenomena are produced by the Moon's *librations*. These are of four kinds. The diurnal motion of the Earth on its axis, carrying the spectator farther north or south, causes the *daily libration of the Moon*.

The *libration of the Moon in longitude* is caused by her uniform motion on her axis, and the irregularity of her motion round the Earth.

The *libration of the Moon in latitude* is caused by the inclination of her orbit to the plane of the ecliptic.

The other is a small *libration*, caused by the attractive force of the Earth on the spheroidal figure of the Moon.

How far is the Moon distant from the Earth? Why is the Moon interesting to us? In what time does the Moon perform a revolution from a point in the ecliptic to the same again? What is her sidereal revolution? What is a lunation? (Why does the Moon always present the same face to us?) What may cause the Moon to turn on its axis? What has been the error of authors respecting the time of the Moon's revolution on its axis? What is the diameter of the Moon? How must the Earth appear to lunarians? What difference is there in the hemispheres of the Moon respecting light? Why does the Moon shine? What is the cause of the Moon's exhibiting different phases? Have the lunarians difference of seasons? Has the Moon an atmosphere? Why does the Moon exhibit dark spots, called the Man in the Moon? Are the mountains in the Moon similar to those of the Earth? Why are the irregularities in the Moon's surface useful to us? If the Moon's surface were covered with water, how would it reflect the Sun's image? What proportion does the light of the Moon bear to that of the Sun, according to different authors? How far distant from the Earth does the Moon appear to a spectator at the Sun? What is the apogee

and perigee of the Moon's orbit? What is syzygy? What did Dr. Herschel think he saw in the Moon? When the Moon is about three or four days old, what does she exhibit? Why do the Sun and Moon appear larger in the horizon than on the meridian? What are the librations of the Moon.

SECTION IX. *Of Mars.*

Mars, in distance from the Sun, is next to the Earth in the solar system. The red, fiery color of this planet attracted the attention of the ancients. Hence they gave it the name of their god of war. Hence also it "is usually represented by this character, ♂, which is said to be rudely formed from a man holding a spear protruded, representing the god of war."

Some have thought the color of Mars may arise from his being of a nature suited to reflect the red rays of light. But the prevailing opinion is, that it arises from the extended and dense atmosphere of the planet. The color of a beam of light, passing through a dense medium, inclines to red; the color always being brightened in proportion to the density of the medium, and the distance passed. The red, the least refrangible rays, seem more strong and vigorous than the violet, the most refrangible rays. The former will traverse an atmosphere, when the latter will be absorbed or diverted. Hence the ruddy appearance of this planet and of the Moon eclipsed; and hence the beautiful tinge of the morning and evening clouds.

In 1665, Dr. Hooke discovered spots on Mars. From a motion perceived in these, he concluded this planet had a rotation on its axis. In 1666, Mr. Cassini observed spots on Mars. By diligent observation on these, at different times, he ascertained that Mars performed a revolution round his axis in 24 hours 40 minutes.

To the inhabitants of the Earth Mars appears sometimes gibbous; sometimes full; never horned. Fig-

ures 4, 5, and 6, of Plate iii, represent different telescopic appearances of Mars. At Fig. 5 he appears gibbous.

Besides the dark spots on Mars, Miraldi observed (a luminous zone round his south pole) which he asserts had been seen by astronomers 60 years before his time. This singular phenomenon is represented in Plate iii, Figs. 5 and 6. At Fig. 5, this spot presents a singular appearance, apparently projecting beyond the disk of the planet, and producing a breach which seems the greater on account of the gibbous appearance of the planet. Other astronomers have observed (a peculiar splendor or brightness at both the poles of Mars.) This is subject to much variation. Dr. Herschel supposes the splendor arises from the snow around the poles; and that the variation in the appearance is caused by the melting of the polar ice.

The greatest distance of Mars from the Earth is about 269,000,000 miles; the least, 49,000,000 miles. Hence this planet, when in conjunction with the Sun, appears 23 times less than when in opposition.

The figure of Mars is an (oblate spheroid,) the equatorial diameter being to the polar nearly as 16 to 15.

To an inhabitant of Mars the Earth must appear as (a morning and evening star) as Venus does to us, but of a less magnitude, and less brilliant. It must exhibit all the phases of the Moon, like Mercury and Venus, to the inhabitants of the Earth.

ELEMENTS OF MARS.

Mean diameter, 4189 miles.

Mean diameter, as seen from the Sun, 6".

Inclination of his orbit to the ecliptic, $1^{\circ} 51' 4''$.

Tropical revolution, 686 d. 22 h. 57 m. 58 s.

Sidereal revolution, 686 d. 23 h. 30 m. 35 s.

Place of ascending node, Taurus, $18^{\circ} 15' 8''$.

Place of descending node, Scorpio, $18^{\circ} 15' 8''$.

Motion of the nodes in longitude for 100 years,
45' 33".

Retrograde motion of the nodes in 100 years, 37' 59".

Place of the aphelion, 5 s. 2° 57' 54".

Motion of the aphelion in longitude for 100 years,
1° 51' 40".

Diurnal rotation, 24 h. 40 m.

Mean distance from the Sun, 144,000,000 miles.

Eccentricity, 13,474,515 miles.

Why was Mars represented by the character ♂? Why does Mars appear of a fiery color? Who discovered spots on Mars? In what time does Mars perform a revolution on his axis? How does Mars sometimes appear to the inhabitants of the Earth? What did Miraldi observe in Mars? What have other astronomers observed in this planet? How much less does Mars appear to us in conjunction than in opposition? What is the form of Mars? How must the Earth appear to the inhabitants of Mars?

SECTION X. *Of the Asteroids.*

The term *Asteroid* is formed from two Greek words, (*asteer*, a star, and *eidos*, appearance.) The term is said to have been first applied by Dr. Herschel.

(The *Asteroids* are four small planets, the orbits of which are between those of Mars and Jupiter.)

Prior to the discovery of the Asteroids, irregularities in the motions of the old planets led some astronomers to suppose there must be a planet between Mars and Jupiter. (The first day of the present century) is memorable for the discovery of an intervening planet: three others were afterwards discovered; so that the astronomer of the present century has the peculiar felicity to know, that not one planet only, but four, occupy the intervening space between Mars and Jupiter.

"These minor planets are also represented by symbols:—(Vesta, by a character resembling an ancient altar, with the sacred fire) Juno, by the symbol of Mercury, with the superior curves turned the contrary way,

and a star between them. The character of Ceres is a sickle, or reaping-hook; and Pallas is represented by the head of an ancient spear.—*Prior's Lectures.*

VESTA.

Vesta, though the nearest of the Asteroids to the Sun, was the last discovered, being first seen by Dr. Olbers, of Bremen, in Lower Saxony, on the 29th of March, 1807. It may be seen in a clear evening by the naked eye. (Its light is more white, pure, and intense than that of the other Asteroids.) It is not surrounded by nebulosity, and has no visible disk.)

Mean diameter of Vesta, 238 miles.

Mean distance from the Sun, 225,000,000 miles.

Inclination of its orbit, $7^{\circ} 8' 46''$.

Tropical revolution, 3 y. 60 d. 4 h.

Place of the aphelion, in 1809, 2 s. $9^{\circ} 42' 53''$.

Longitude of ascending node, 3 s. $13^{\circ} 1' 0''$.

Eccentricity, 20,974,725 miles.

JUNO.

Juno, or Harding, was discovered by Mr. Harding) of Lilienthal, near Bremen (September 1st, 1804.) Appearing like a star of the eighth magnitude,) it is of a reddish color, free from the nebulosity observable in Pallas. Yet it may be concluded from Mr. Schroeter's observations, that (it must have an atmosphere) more dense than any of the primary planets, except the Asteroids. A remarkable variation in the brilliancy of Juno was observed by this astronomer. He attributed this to the changes taking place in the atmosphere. He thinks, however, these changes may arise from a diurnal rotation in 27 hours.

The most singular circumstance respecting Juno, is (the great eccentricity of its orbit) as may be seen by inspection of the elements.

Mean diameter of Juno, 1,425 miles.

Mean distance from the Sun, 252,000,000 miles.

Inclination of its orbit, $13^{\circ} 3' 28''$.

Tropical revolution, 4 y. 128 d.

Place of aphelion in 1809, 7 s. $29^{\circ} 49' 33''$.

Longitude of ascending node, 5 s. $21^{\circ} 6' 37''$.

Eccentricity, 63,241,920 miles.

CERES.

(The discovery of Ceres, as we have seen, led the van of discoveries in the present century. It was made by (Piazzi, astronomer royal at Palermo, on the first day of January, 1801.) According to some, it is about the size of the Moon, appearing like a star of the eighth magnitude. Dr. Herschel's measurement, however, made its diameter 13 times less than that of the Moon.

The planet Ceres is of a ruddy color, though not very deeply tinged. Examined by a magnifying power of about 200, it exhibits a disk surrounded by a dense and extended atmosphere. By many observations, Mr. Schroeter found this atmosphere (subject to various changes,) and extended to the great height of 675 miles. But little opportunity is given for discovering the diurnal rotation of this planet, the visible hemisphere being interchangeable, overshadowed, and clear.

(The atmosphere of Ceres, like that of the Earth, very dense at the planet, and more rare at a distance, produces singular variations in its apparent diameter.) The disk seems to enlarge when the planet is approaching the Earth, much faster than might be expected from the diminution of distance.

Mean diameter of Ceres, 163 miles.

Do. according to Schroeter, 1,624 miles.

Mean distance from the Sun, 263,000,000 miles.

Inclination of its orbit, $10^{\circ} 37' 34''$.

Tropical revolution, 4 y. 220 d. 12 h. 53 m. 34 s.

Place of aphelion, in 1802, 4 s. $25^{\circ} 57' 15''$.

Longitude of ascending node, 2 s. $21^{\circ} 6' 0''$.
 Eccentricity, 21,410,830 miles.

PALLAS.

Pallas, discovered by Dr. Olbers, on the 26th of March, 1802, is in (magnitude nearly the same as Ceres, but of a color less ruddy.) It is surrounded with nebulosity, similar in appearance to that of Ceres, and extended to a height almost equal. In the eccentricity of its orbit, it resembles Juno. Pallas is distinguished from all the other primary planets by the great inclination of its orbit to the plane of the ecliptic, being about 35° ; nearly five times the inclination of Mercury's orbit.

Mean diameter of Pallas, according to Herschel, 80 miles.

Do. according to Schroeter, 2,099 miles.

Mean distance from the Sun, 265,000,000 miles.

Inclination of its orbit, $34^{\circ} 39' 0''$.

Tropical revolution, 4 y. 7 m. 11 d.

Place of aphelion in 1802, 10 s. $1^{\circ} 7' 0''$.

Longitude of ascending node, 5 s. $22^{\circ} 28' 57''$.

Eccentricity, 65,269,500 miles.

The mean distances of these Asteroids from the Sun being comparatively equal, but the inclination of their orbits, and the position of the line of their apsides, different, their orbits intersect each other. (Plate i. Fig. 3.) Whether they will ever come in conflict is uncertain, but may be determined by future observations and the calculation of succeeding astronomers. We know they are guided by infinite wisdom.

Much labor and ingenuity have been employed to show, that these Asteroids are but fragments of a larger planet burst asunder by some vast explosion. The hypothesis seems not supported by conclusive arguments. Against it there are strong reasons. The idea itself of such an explosion seems extravagant beyond conception. How vast must have been the force which could

throw such bodies from each other to a distance of 40 millions of miles ; or so as to revolve in orbits 40 millions of miles distant ! Immense is the explosive force of Hecla, throwing lava or cinders to the distance of 150 miles. But how diminutive ! How are all the explosions of Vesuvius and Hecla, of Etna and Cotopaxi, annihilated in comparison ! Had these Asteroids constituted but one planet, since the first attention to the heavenly bodies, it would have been seen by ancient astronomers, being sufficiently large for observation by the naked eye. It would have been enumerated among the planets. It may be added, that the vast atmosphere of some of these planets, which would, without doubt, have been left behind in such an explosion, seems directly opposed to the idea of their having been hurled from a bursting planet.

Of what is the term *Asteroid* compounded ? What are the Asteroids ? What caused some astronomers to suppose there was a planet between Mars and Jupiter ? On what day was the first of the Asteroids discovered ? By what characters are the Asteroids represented ? When and by whom was Vesta discovered ? How does its light differ from that of the other Asteroids ? Has it nebulosity or a disk ? Who discovered Juno ? When ? What are the apparent magnitude and color of Juno ? Has it an atmosphere ? What is the most singular circumstance respecting Juno ? What led the van of discoveries in the present century ? When was Ceres discovered ? By whom ? What is the color of Ceres ? What kind of atmosphere has this planet ? What produces singular variations in its apparent diameter ? What are those variations ? Who discovered Pallas ? At what time ? How are its magnitude and color ? Has it nebulosity or an atmosphere ? In what is it distinguished from all the primary planets ? What is remarkable in the orbits of the Asteroids ? What have much labor and ingenuity been employed to show ? What objections can be offered to the hypothesis that the Asteroids formerly constituted but one planet ?

SECTION XI. *Of Jupiter.*

Beyond the Asteroids, or farther distant from the Sun, is Jupiter, the largest of the planets. Jupiter, next to

Venus, is the most brilliant of the planets.) He sometimes even surpasses her in brightness. The form of Jupiter is an (oblate spheroid,) his equatorial diameter being to his polar, as 14 to 13.

The character \mathcal{Z} , by which this planet is represented by astronomers, is a zeta, the first letter of his Greek name, *Zeus*; the lower part cut off by a small line drawn across, as a sign of abbreviation.

The most remarkable phenomena in the disk of Jupiter is a number of belts or stripes by which he is encompassed. (These appear variable at different times,) and even at the same time, viewed by telescopes of different powers. Yet they generally appear parallel to each other, and parallel to the equator of Jupiter. In very favorable weather, they sometimes seem formed of a number of curved lines, like the strokes of an engraving. Eight or ten belts have been seen at the same time. The belts have been observed, at times, of different breadths, and have afterwards all assumed nearly the same breadth. (Bright and dark spots) are frequently visible in these belts. Like the belts, the spots are subject to continual change. When a belt vanishes, the contiguous spots disappear. Some of the spots, however, seem to make periodical returns.) The spot first observed by Cassini re-appeared eight times between the years 1665 and 1708. In 1713, it again re-appeared, in the same form and position. In 1780, May 28, the disk of Jupiter was observed by Dr. Herschel, covered with small, curved belts, or rather lines not contiguous, as in Plate iii, Fig. 7 and 8. Parallel belts, however, as represented in Plate iii, Fig. 9, are most common.

Different opinions are formed by astronomers respecting the cause of these appearances. By some they are considered the effect of changes in the atmosphere surrounding Jupiter, while they are regarded by others as indications of great physical revolutions on the surface of the planet.) By others, again, it is supposed that the

clouds of Jupiter, partaking the great velocity of his diurnal motion, are formed into strata, parallel to his equator, that the clouds reflect more light than the body of Jupiter, and that the belts are the body seen through the parallel interstices of the clouds. "But whatever be the nature of these belts," says Mr. Dick, "the sudden changes, to which they are occasionally subject, seem to indicate the rapid operations of some powerful physical agency—for some of these are more than 5,000 miles in breadth—and, since they have been known to disappear in the space of an hour or two, and even during the time of a casual observation, agents more powerful than any with which we are acquainted, must have produced so extensive an effect."

ELEMENTS OF JUPITER.

Mean diameter, 89,170 miles.

Mean diameter, as seen from the Sun, $37''.7$.

Inclination of his orbit to the ecliptic, $1^{\circ} 18' 51''$.

Tropical revolution, 11 y. 314 d. 8 h. 41 m. 3 s.

Sidereal revolution, 11 y. 314 d. 22 h. 19 m.

Place of ascending node, Cancer, $8^{\circ} 42' 33''$.

Place of descending node, Capricorn, $8^{\circ} 42' 33''$.

Motion of the nodes in longitude for 100 years, $59' 30''$.

Retrograde motion of the nodes in 100 years, $24' 2''$.

Place of the aphelion, 6 s. $11^{\circ} 37' 40''$.

Motion of the aphelion in longitude for 100 years, $1^{\circ} 34' 33''$.

Diurnal rotation, 9 h. 55 m. 37 s.

Mean distance from the Sun, 490,000,000 miles.

Eccentricity, 23,762,635 miles.

SATELLITES OF JUPITER.

Jupiter is attended by four satellites. They are reckoned the first, second, third, and fourth, beginning with the one nearest to the primary. These satellites were

discovered by Galileo, on the 8th of January 1610, and called by him *Mediceæ sidera*, *Medicean stars*, in honor of his patrons, the family of the Medici.

By some, we are told these satellites are not to be seen by the naked eye. But Prior, in his *Lectures on Astronomy*, informs us, that, "with the exception of the third and fourth, they are never visible to the naked eye; instances of these two being so seen are extremely rare, although they have been known to occur." He tells us, in another place, that, "according to Dr. Herschel, the third is the largest; the second the least; and the first and fourth are nearly of the same size. They are all of them supposed to be considerably larger than the Earth; but their dimensions are not exactly known."

Through a good telescope, the satellites of Jupiter present a delightful prospect. They seem generally ranged in a straight line, parallel, or nearly parallel, to his belts. Jupiter and his satellites eclipse each other. Like the Moon, they throw their dark shadows upon their primary; and, like her, they fall into his shadow and are eclipsed. These phenomena are a demonstration, that those distant luminaries are in themselves opaque, and shine not by their own light, but by rays borrowed from the Sun.

The eclipses of Jupiter's satellites are of great utility to us. By these it is found that light is progressive, which, before their discovery, was supposed to be instantaneous. By them, the relative distances between the Earth, the Sun, and Jupiter, can be ascertained. But the greatest benefit derived from these eclipses, is to geography and navigation. They afford one of the best methods yet known for ascertaining longitude. It could not have occurred to Galileo, when he first discovered these satellites, that, by an act so simple, he was rendering so great a benefit to mankind. Here is verified the observation of a celebrated traveller, that the Deity, every where, brings the greatest events from causes apparently the least.

Satellites.	Periodical times.					Distances from primary in miles.
1	1 d.	18 h.	28 m.	36 s.		266,000
2	3	13	17	54		423,000
3	7	3	59	36		676,000
4	16	18	5	6		1,189,000

How is Jupiter in magnitude and brilliancy? What is his form? What is his character? What is the most remarkable phenomenon in the disk of Jupiter? How do his belts appear? What have been visible in the belts? What do some of the spots appear to do? What opinions have been formed respecting the cause of the apparent spots and belts on the disk of Jupiter? What do the sudden changes in Jupiter's belts seem to indicate? How broad are some of the belts? By whom were the satellites of Jupiter discovered? What year? Can these satellites be seen by the naked eye? What does Prior say of their magnitude? What prospect do they present through a good telescope? Of what are the eclipses of Jupiter and his satellites a demonstration? Why are the eclipses of Jupiter's satellites of great use to us? What is verified by them?

SECTION XII. *Of Saturn.*

Beyond Jupiter, in the solar system, is Saturn, formerly considered (the most remote of the planets.) He shines with a (dull, pale, leaden light.)

The character of Saturn, ♄ , is a scythe, rudely represented; according to some, an old man leaning on a staff. In heathen mythology, Saturn was the father of Jupiter.

(Belts and dark spots) have been discovered on the disk of Saturn. Five belts, nearly parallel to the equator, were observed by Huygens. Several, nearly parallel to the ring, and more extensive in proportion to the body of the planet, than those of Jupiter, were seen by Dr. Herschel. By the spots of Saturn changing their position, his diurnal rotation was determined by Dr. Herschel to be 10 h. 16 m. 0.44 s. Guy, in his *Astronomy*, informs us, "later accounts say, 12 h. 13 $\frac{1}{4}$ m."

To an inhabitant of Saturn, the Sun's light and heat must be about 90 times less than they are to us.) -

Viewed with a good telescope, Saturn appears of a spheroidal figure. A remarkable circumstance is, the flattening at the poles does not seem to commence till the high latitude of $43^{\circ} 20'$. According to Dr. Herschel, the proportion of his disk is,

Diameter of the greatest curvature,	36
Equatorial diameter,	35
Polar diameter,	32

The most remarkable phenomenon of Saturn is (a ring with which he is encompassed.) Something extraordinary in the appearance of this planet was discovered by Galileo. It seemed a large globe between two smaller globes. This discovery he announced in 1610. Continuing his observations till the year 1612, to his surprise the smaller globes disappeared, and the larger remained apparently alone. But, after some time, the smaller globes again appeared on each side of the larger globe, changing their form as he continued his observations; appearing, at different times, round, semicircular, oblong like an acorn, with horns towards the globe, becoming, gradually, so long and wide as to encompass it with an elliptical ring. "Upon this, Huygens set about improving the art of grinding object-glasses, and made telescopes which magnified two or three times more than any which had been before made, with which he discovered very clearly the ring of Saturn; and, having observed it for some time, he published the discovery in 1656."

The ring of Saturn is (double,) or, rather, consists of two concentric rings, detached from each other, and from the body of the planet. In Plate ii, Saturn and his double ring are represented as in the largest view, when seen from the Earth. In Plate iii, Fig. 10, he appears as if viewed by a spectator at right angles to the plane of the ring. In Plate iii, Fig. 11, the ring is represented very obliquely to the view of the observer. Its inclination to the ecliptic is 31° . The two parts of the ring lie in the same plane, performing a

revolution round an axis perpendicular to that plane, in 10 h. 32 m. 15 s. It is visible to us when the Sun is on the same side of its plane with the Earth, but at no other times. A deep shadow is cast by the ring on that part of Saturn which is opposite to the Sun. In this dark shadow, each half of the planet, in succession, must be enveloped for almost fifteen of our years, or during one half of Saturn's annual revolution. During the same term, each, in succession, must be illuminated by the double ring, the light of which is more brilliant than that of the planet itself.

The ring of Saturn is considered by Dr. Herschel, not as a shining matter, or aurora borealis, as supposed by some, but solid and dense, as the body of the planet.

DIMENSIONS OF THE RING.

	Miles.
Inner diameter of the interior ring,	146,346
Exterior diameter,	184,393
Inner diameter of the external ring,	190,248
Exterior diameter,	204,883
Breadth of the inner ring,	19,024
Breadth of the external ring,	7,317
Breadth of the vacant space,	2,927

ELEMENTS OF SATURN.

Mean diameter, 79,042 miles.

Mean diameter, as seen from the Sun, 18".

Inclination of his orbit to the ecliptic, $2^{\circ} 29' 34.8''$.

Tropical revolution, 29 y. 162 d. 11 h. 30 m. 0 s.

Sidereal revolution, 29 y. 167 d. 0 h. 27 m. 0 s.

Place of the ascending node, Cancer, $22^{\circ} 12' 57''$.

Place of the descending node, Capricorn, $22^{\circ} 12' 57''$.

Motion of the nodes in longitude, for 100 years, $52' 35''$.

Retrograde motion of the nodes in 100 years, $30' 57''$.

Place of the aphelion, 8 s. $2^{\circ} 38' 18''$.

Motion of the aphelion in longitude, for 100 years,
 $1^{\circ} 50' 7''$.

Diurnal rotation, 10 h. 16 m.

Mean distance from the Sun, 900,000,000 miles.

Eccentricity, 50,958,399 miles.

SATELLITES OF SATURN.

Saturn has seven satellites, revolving about their primary, and accompanying him in his revolution round the Sun.

Satellites.	Periodical times.				Distances from primary in miles.
1	0 d.	22 h.	37 m.	22 s.	107,000
2	1	8	53	8	135,000
3	1	21	18	27	170,000
4	2	17	41	22	217,000
5	4	12	25	12	303,000
6	15	22	41	13	704,000
7	79	7	48		2,050,000

The seventh satellite of Saturn is, by some, reckoned the fifth. (This satellite is remarkably bright at its greatest western elongation, surpassing all the others but one in lustre. Very small at other times, it entirely disappears at its greatest eastern elongation.) This phenomenon was first observed by Cassini. It may arise from one part of the satellite being more luminous than the other parts. It was observed through all the variations of light by Dr. Herschel. He concluded that, like the satellites of Jupiter and our Moon, it revolved on its axis at the same time that it performed a revolution round its primary.

"There is not, perhaps," says Dr. Herschel, "another object in the heavens, that presents us with such a variety of extraordinary phenomena, as the planet Saturn; a magnificent globe, encompassed by a stupendous double ring; attended by seven satellites; ornamented with equatorial belts; compressed at the

poles; turning upon its axis; mutually eclipsing its ring and satellites, and eclipsed by them; the most distant of the rings also turning upon its axis, and the same taking place with the farthest of the satellites; all the parts of the system of Saturn occasionally reflecting light to each other; the rings and the moons illuminating the night of the Saturnian; the globe and the satellites enlightening the dark parts of the rings; and the planet and the rings throwing back the Sun's beams upon the moons, when they are deprived of them at the time of their conjunctions."

How was Saturn formerly considered? With what light does he shine? What does the character of Saturn, h , represent? What have been discovered on the disk of Saturn? What kind of belts were seen by Herschel? In what time does Saturn turn on his axis? How are the Sun's light and heat at Saturn? What is the form of Saturn? What is the most remarkable phenomenon of Saturn? How did the ring first appear to Galileo? When did he announce his discovery? How did Huygens discover that the object seen by Galileo was a ring? Is the ring of Saturn single or double? How is it inclined to the ecliptic? When is the ring visible to us? How long is each half of Saturn, in succession, enveloped in the dark shadow of the ring? What substance did Dr. Herschel consider the ring of Saturn? How many satellites has Saturn? What is remarkable in the appearance of the seventh? What does Dr. Herschel say of the phenomena of Saturn?

SECTION XIII. *Of Herschel.*

Herschel, Uranus, or Georgium Sidus, was unknown, as a planet, to the scientific world, till the year 1781.) On the 13th of March, in that year, it was discovered by the celebrated astronomer whose name it usually bears in this country. Before the discovery, it had probably been seen by astronomers, but had attracted no particular attention. Prior, in his Lectures, tells us, "it had been observed by Flamsteed and Mayer, but was considered by them as a fixed star, and, as such, introduced into their catalogues." Viewing the small stars near the foot of Gemini, Dr. Herschel was struck with

the appearance of one, less brilliant than the rest, but surpassing them in magnitude. He suspected it to be a comet.) Observing it with different telescopes, he found that, contrary to the fixed stars, its disk appeared to increase with the magnifying power of the glasses. He found also, by measuring its distance from some of the fixed stars, at different times, that it moved about $2\frac{1}{4}''$ in an hour. That it was a planet, first occurred to Dr. Maskelyne)

The name *Georgium Sidus*, or Georgian star, was given to this planet by Dr. Herschel, in (compliment to his patron George III.) the then reigning king of Great Britain. It is often called *Uranus*, in European publications. Uranus, in heathen mythology, was the father of Saturn.

This planet is so distant, it is scarcely visible to the naked eye. In a serene sky, however, it appears like a star of the sixth magnitude, shining with a bluish-white light, and a brilliancy between the splendor of the Moon and that of Venus.

Such is the immense distance of this planet, that no observations have been made upon it, by which the time of its diurnal revolution can be determined. A

Herschel is denoted by this character, H (the initial of a name immortal as human science;) "the horizontal bar being crossed by a perpendicular line, forming a kind of cross, the emblem of Christianity, denoting, perhaps, its discovery was made in the Christian era." The ball, however, represented as pendent from the H, may be a globe or planet, as hanging on the discovery of the astronomer Herschel.

ELEMENTS OF HERSCHEL.

Mean diameter, 35,112 miles.

Mean diameter as seen from the Sun, $4''$.

Inclination of his orbit, $0^{\circ} 46' 26''$.

Tropical revolution, 83 y. 305 d. 7 h. 21 m.

Sidereal revolution, 84 y. 8 d. 9 h. 33 m.

Place of the ascending node, Gemini, $12^{\circ} 59' 4''$.

Place of the descending node, Sagittarius, $12^{\circ} 59' 4''$.

Motion of the nodes in longitude for 100 years, $26' 10''$.

Retrograde motion of the nodes in 100 years, $57' 22''$.

Place of the aphelion, 11 s. $17^{\circ} 48' 6''$.

Motion of the aphelion in longitude for 100 years,
 $1^{\circ} 28' 0''$.

Mean distance of the planet from the Sun, 1,800,000,000 miles.

Eccentricity, 86,263,800 miles.

SATELLITES OF HERSCHEL.

Six satellites have been discovered, accompanying Herschel in his dark and tedious round. "It is remarkable," says Prior, "that these satellites revolve in a retrograde direction, or contrary to the order of the signs, in orbits lying nearly in the same plane, and almost perpendicular to the plane of the planet's orbit." This statement is corroborated by other accounts. The satellites of Herschel were all discovered by Dr. Herschel.

Satellites.	Periodical times.				Distance from primary in miles.
1	5 d.	21 h.	25 m.	20 s.	230,335
2	8	16	57	47	298,838
3	10	23	2	47	348,388
4	13	10	56	29	399,593
5	38	1	48	0	746,240
6	107	16	39	56	1,597,708

When was the planet Herschel discovered? By whom? If it had been before seen, what had it been considered? How was Dr. Herschel employed when he discovered this planet? To whom did it first occur that it was a planet? Why did Dr. Herschel call it Georgium Sidus? How does it appear to the naked eye? Has its diurnal rotation been determined? Why is Herschel denoted by this character, ♄? How many satellites has Herschel? What is remarkable in the motion of these satellites?

CHAPTER II.

Causes of the Planetary Motion.

MATTER is in itself (inactive) and moves but as impelled by external force. An impulse being given to a body, it passes in (a right line,) till turned out of its course by a different impulse, not in direct coincidence or opposition to the former. Uninterrupted, it would forever move in the same direction, and at the same rate, or over equal distances in equal times. After every new impulse, it will take a new direction, and pass in a diagonal between its former course and the direction of the new impulse. Let the body at A, [Plate v. Fig. 9,] be impelled by a momentum sufficient to carry it in a given time from A to B. It would, uninterrupted, move from B to C, and from C to D, equal distances in equal times. But if, at B, it receive an impulse in the direction B E, sufficient to carry it to E in the same time that the former motion would carry it to C, it would move in the diagonal B F, and be found at F at the same time that it would have arrived at C, unaffected by the impulse last given.—See *Enfield's Philosophy, Book II. Chap. iii. Proposition 14.*

Circular or elliptical motion is the effect, not merely of (an impulse in one direction,) but of such an impulse and a continued action forcing a body from a right line towards a centre. The planets all move in ellipses, differing, however, but little from (circles,) except the orbits of Juno and Pallas. They are kept in their orbits by the (projectile force) given at their formation by the Creator, and the constant force of gravity, or the Sun's attraction. Let A, a planet, [Plate vi. Fig. 1,] be projected along the line A B C, meeting with no resistance, it would forever retain the same velocity, and the same direction. The force, which would carry it from A to B

in a given time, would, in an equal time, carry it from B to C, and from C to D. But if, at B, it fall into the attraction of S, the Sun, which should so balance the projectile force as to carry it to E, at the same time that it would, by its former motion, have arrived at C, the planet would now revolve in a circle, B E F. But should the attraction of S be more powerful in proportion to the projectile force, it might bring the planet to G instead of E, or, being stronger, might carry it nearer the line B S, in any given proportion. If carried to G, it would revolve in the ellipse B G H. Before it arrives at G, and for some distance after, the lines of motion, caused by the projectile and centripetal forces, form an acute angle. The two powers, then, augment the motion caused by each other; and, attraction increasing as the squares of the distances decrease, the motion of the planet would be accelerated all the way from B to H. At H, it would be nearer the centre of attraction than at B, by twice the eccentricity of its orbit, and, being much more powerfully attracted, would be drawn to S, were not the projectile force also increased. This would now be so augmented, that it would carry the planet from H to I in the same time that attraction would bring it to S. It would then be found at L, and proceed to B, completing the revolution. In passing from F to B, the planet would be as much retarded in its motion by gravity, as accelerated in its motion from B to F.

Thus it appears "that bodies will move in all kinds of ellipses, whether long or short, if the spaces they move in be void of resistance. Only those which move in the longer ellipses, have so much the less projectile force impressed upon them, in the higher parts of their orbits." Gravity in one part of an orbit becomes projectile force in another. What is gravity at B is projectile force at M. It operates principally by oblique action. This is immensely increased all the way from B to M.

A double projectile force will always balance a quadruple power of gravity. The projectile force is greater

in proportion to the centripetal, as the orbit is larger in which the planet moves. In the annual revolution of the Earth, if an angle of one degree be taken at the centre, the projectile force is to the centripetal about as 103 to 1. The disproportion is still greater in the orbits of the superior planets; greatest in that of Herschel.

The solar attraction at Herschel is 3,240,000,000,000,000,000 times less than it is one mile from the Sun. To us it is inconceivable, that such a diminished attraction can have any perceptible effect at the Georgium Sidus. It must, however, be remembered, that the planets move without resistance in an empty void. That bodies, balanced as they are, can be moved by a very small force, cannot be doubted. Attraction withdrawn, we know not but Archimedes could have made good his assertion, by the force of his hand. That bodies so immense, however, and so immensely distant from each other, should all revolve in perfect harmony, may well excite the admiration of limited mortals; but must be infinitely easy to Almighty Power, that, at the creation, "*spake, and it was done.*"

How is matter in itself? If a body be put in motion by an impulse, how would it pass? Of what is circular or elliptical motion the effect? In what figures do the planets move? How are they kept in their orbits? What does gravity in one part of an orbit become in another? What will a double projectile force balance? Does the proportion of the projectile force increase as the orbit is larger? In what orbit is the proportion of the projectile force greatest? Can the solar attraction have any perceptible effect at Herschel? If attraction were withdrawn, what is it possible Archimedes could have done? What power keeps the orbits duly balanced?

* "Give me where I may stand, and I will move the Earth." This was applied by the celebrated Syracusan to the mechanical force of the lever, but may be true in respect to the movement of the planets in empty void.

CHAPTER III.

*Prospect of the Heavens, as seen from different Parts of the Solar System.*SECTION I. *Prospect at the Sun.*

(AT the centre) only can a just view be had of the solar system. Stationed there, a spectator would see all the primary planets moving in harmonious order) from west to east. He might take the periodical time of one, perhaps Mercury, by which to measure the revolutions of the rest. From (their periodical times) and (apparent diameters) he might form some conjecture of their distances and magnitude. As all do not move in the same orbits, their paths would appear to cross each other at very small angles. The orbits being elliptical, but the line from any planet to the spectator passing equal areas in equal times, the spaces measured by such planet in a given time, would (appear unequal). Some variation in the diameter of each planet would also be apparent. The fixed stars would appear (equally distant, and all at rest.)

Where only can a just view be had of the solar system? Stationed at the Sun, how would a spectator see the primary planets move? By the periodical time of what planet might he measure the revolutions of the rest? From what could he form a conjecture of the distances and magnitude of the planets? Would the spaces measured by a planet in a given time appear equal? How would the fixed stars appear?

SECTION II. *Prospect at Mercury.*

A different view would be presented at Mercury. A spectator at this planet being, by the whole diameter

of Mercury's orbit, nearer to the other planets at some times than at other times, their diameters would appear to vary inversely as their distances.) To such a spectator (Venus and the Earth would appear superior planets.) These, and all the planets farther distant, would have conjunctions and oppositions.) Their motions would appear sometimes direct, sometimes retrograde.) They would seem stationary at intervals. If Mercury have not a rotation on his axis, a succession of day and night would scarcely be suggested to such a spectator. He might, however, observe the diurnal rotation of the other planets.

Why would the diameter of the planets seem to vary at Mercury? In what proportion would they seem to vary? Would the other planets at Mercury appear to be superior, or inferior? Would they appear to have conjunctions only, or conjunctions and oppositions? How would their motions appear?

SECTION III. *Prospect at the Earth.*

The prospect at the Earth is best known to its inhabitants. The inferior planets have two conjunctions in every synodical revolution; the superior planets have conjunctions and oppositions in succession.) The planets seem to enlarge or diminish as they are nearer or farther distant.) The inferior planets by the position of their illuminated sides, assume all the phases of the Moon. By the rotation of the Earth on its axis, the Sun, the planets, and the fixed stars, appear to have a diurnal revolution from east to west.

Where is the prospect of the solar system best known to the inhabitants of the Earth? What planets appear to have conjunctions only, and what conjunctions and oppositions? Why do the planets appear larger at some times than at others? Which of the planets exhibit the phases of the Moon?

SECTION IV. *Prospect at Jupiter.*

(To beings like ourselves, with eyes unassisted by glasses, it can scarcely be known, at Jupiter, that there are inferior planets.) (The greatest elongation of the Earth would not exceed $11^{\circ} 11'$; that of Mars, $17^{\circ} 13'$.) By means of equatorial telescopes, however, planets may be seen extremely near the Sun.

Can it be known at Jupiter that there are inferior planets? At Jupiter what would be the greatest elongation of the Earth and Mars? By what means can planets be seen very near the Sun?

SECTION V. *Prospect at Herschel.*

An inhabitant of this Earth, transported to Herschel, would almost lose sight of the solar system. To him the Earth could never appear more than $3^{\circ} 2'$ from the Sun; Mars, $4^{\circ} 38'$; Jupiter, $15^{\circ} 48'$. Of these, without the assistance of glasses, he would not be likely to have a view, nor to have any knowledge, unless he had been an astronomer in this world. This, however, may depend on circumstances, particularly the atmosphere of Herschel. ; But Saturn, having his greatest elongation 30° , might often be seen exhibiting, his ring excepted, all the phases of the Moon. To such an inhabitant, however, Saturn might not be the only planet visible. We know not but there may be planets in the system still farther distant from the Sun, well known to the inhabitants of the Georgium Sidus; for Almighty Power is not bounded by our limited view.

If an inhabitant of this Earth were transported to Herschel, could he have a view of the solar system? To him, how far would the Earth and the other planets appear from the Sun? May it be that the inhabitants of Herschel see other planets unknown to us?

CHAPTER IV.

Comets.

THE term *comet* is derived from the Latin *cometa*. This is a derivative from *coma*, a head or lock of hair. The original is a Greek primitive, *comee*, hair. Without doubt, comets are so called (from the train or tail) they exhibit when in the vicinity of the Sun.

(Comets are large heavenly bodies, moving round the Sun in various directions, and in orbits very eccentric. They seem to come from some far distant region, make a short circuit round the Sun, and then retire to their unknown bound.) By the unlearned, they are often called (*blazing stars*.) It is not strange, if, as has been represented, in the days of barbarism and superstition, comets were considered portentous; if they were regarded as the harbingers of war, famine, and pestilence; if they presented to the frightened imaginations of men the convulsions of states, the dethronement of princes, and the fall of empires. Even among the ancients, however, men of science regarded them in a very different light. Such men so far observed the motions of comets, as to form ideas of them in some measure consonant to modern philosophy. By the Chaldeans, they were considered as planets; and such they were regarded by the Pythagorean philosophers of Italy.

Astronomers of the present day view comets not only as harmless, but designed, by the all-wise Creator, for benevolent and important purposes; though most of those purposes must be unknown to us, or deduced by reasoning from analogy.

There is a great diversity in comets. When viewed through a good telescope, a comet generally resembles a

mass of aqueous vapor surrounding a dark nucleus.) The shades of appearance are very different in different comets. Even the nucleus seems wanting in some. Comets of this kind were observed by Dr. Herschel; some by the sister of that astronomer. Approaching the Sun, the nebulous light of a comet becomes more brilliant, and its luminous train increases in length. At the perihelion its heat is greatest, and the length of its train the most extensive. Here the comet sometimes shines with all the splendor of Venus. Its brilliancy decreases as it retires from the perihelion, till it reassumes its nebulous appearance. "History records," says Dr. Rees, "that some comets have appeared as large as the Sun." One of this magnitude is said to have been visible at Rome in the reign of Nero. "The astronomer Hevelius also observed a comet, in 1652, which did not appear to be less than the Moon, though it was deficient in splendor, having a pale, dim light, and exhibiting a dismal aspect."—*Wilkins's Astronomy*.

The number of comets which have been seen within the limits of the solar system is not known. It has been stated at from 350 to 500.

Some comets have approached nearer to the Sun than any of the planets. Of ninety-eight, whose elements have been computed, twenty-four passed between the Sun and the orbit of Mercury; thirty-three between the orbits of Mercury and Venus; twenty-one between the orbits of Venus and the Earth; sixteen between the orbits of the Earth and Mars; three between the orbits of Mars and Ceres; and one between the orbits of Ceres and Jupiter.

The tails of comets sometimes occupy an immense space. The comet of 1681 stretched its tail across 104° ; that of 1769 subtended an angle of 60° at Paris, 70° at Boulogne, 97° at the Isle of Bourbon.

By some, the tails of comets have been considered the rays of the Sun, transmitted through the nucleus of the comet, believed to be transparent like a lens.

This was the opinion of Appian, Cardan, and Tycho Brahe. Kepler thought the tail was formed by the solar rays driving away the denser parts of the comet's atmosphere. Euler thinks there is a great affinity between the aurora borealis, the zodiacal light, and these tails; and that the cause of them all is the action of the Sun's light on the atmosphere of the Earth, the Sun, and the comets.

The hypothesis of Dr. Hamilton, of Dublin, deserves particular consideration. He supposes the tails of comets to be streams of electrical light. The doctor supports his opinion by these arguments: "A spectator at a distance from the Earth would see the aurora borealis in the form of a tail, opposite to the Sun, as the tail of a comet lies. The aurora borealis has no effect upon the stars seen through it, nor has the tail of a comet. The atmosphere is known to abound with electric matter; and the appearance of the electric matter in vacuo resembles exactly that of the aurora borealis, which, from its great altitude, may be considered in as perfect a vacuum as we can make. The electric matter in vacuo, suffers the rays of light to pass through without being affected by them. The tail of a comet does not expand itself sideways, nor does the electric matter. Hence he supposes the tails of comets, the aurora borealis, and the electric fluid, to be the same kind of matter." It may be added, in confirmation of this hypothesis, that many astronomers have observed an undulatory motion in the tails of comets, similar to what is sometimes seen in the aurora borealis. About the close of the revolutionary war, the aurora borealis was most extensive and brilliant in the United States. This, with vast undulations, covered the whole northern half of the hemisphere, collecting into a beautiful centre in the zenith. To a spectator on a distant planet, this might give the Earth an appearance resembling, in some measure, the blazing effulgence of a comet.

From what is the term *comet* derived? Why are comets so called? What are comets? Whence do they seem to come, and what to do? How have they been considered by the unlearned? Had any of the ancients just views of comets? How do astronomers of the present day view them? What is the general appearance of comets? Is there much variety in their appearance? How large have some comets appeared? What number of comets has been seen within the solar system? How near the Sun have some comets approached? How large a space have the tails of some comets occupied? What have been the different opinions of authors respecting the tails of comets? Whose opinion seems best supported? May the Earth ever have had the appearance of a comet? When did the aurora borealis appear most brilliant in the United States?

CHAPTER V.

Equation of Time.

THOUGH the apparent motion of the Sun has been used as a measure of time from the greatest antiquity, yet accurate observation has shown it is far from being uniform. The Sun is either faster or slower than a well-regulated clock or watch, during most of the year. (At four times only do they coincide, viz. the 14th of April, the 15th of June, the 31st of August, and the 23d of December.) From the 14th of April to the 15th of June, the Sun is fast of clock; from the 15th of June to the 31st of August, it is slow of clock; from the 31st of August to the 23d of December, it is fast of clock; from this time to the 14th of April, it is slow of clock. From the difference of longitude, the days of coincidence are not all the same in the United States as in Europe. About the 1st of November, the Sun is 16 m. 14 or 15 s. fast of clock. This is the

greatest inequality. The difference is caused by the elliptical figure of the Earth's orbit, and the obliquity of the equator to the plane of the ecliptic.

The orbit of the Earth being elliptical, like the other planetary orbits, with the Sun in one of the foci, the Earth, in its annual revolution, moves more slowly in the aphelion than in the perihelion, as has been before shown. But, the motion on its axis being perfectly uniform, any given meridian will come round to the Sun sooner at the aphelion than at the perihelion. Hence the solar day will be shorter at the former, and longer at the latter, than that measured by an accurate time-keeper.

Let S be the Sun, [Plate v. Fig. 8.] E the Earth; AMP the Earth's orbit; A the aphelion, P the perihelion; the line MS the mean proportional between the semi-axes of the orbit; m a point in the equator represented by the external circle of the Earth, E . Let the spaces ASa , MSn , PSp , represent equal areas of the orbit. The arches of these, by the great law of Kepler, represent the Earth's motion in equal times, as a solar day. It is evident that the point m , when the Earth is at a , at n , or at p , must pass from m to the line ES to complete a solar day. It is also evident, that it must pass farther when the Earth is at p than when it is at a , the distance at n being a mean between the extremes. A day, therefore, measured by the Sun, will agree with that shown by a good time-keeper when the Earth is at M . At A it will be shorter, and at P longer, than the true day of the clock.

By this equation the Sun would be faster than the clock, while the Earth is passing from the aphelion to the perihelion of its orbit; slower than the clock, while the Earth is passing from the perihelion to the aphelion. At either apsis the Sun and clock would coincide. The difference between the Sun and clock would increase, while the Earth is passing from the aphelion or perihe-

lion to the mean distance between them, and decrease while it is passing to the other apsis. The greatest difference arising from this equation is $7' 43''$. The Earth being in the aphelion on the first or second day of July, in the present century, and in the perihelion on the last day of December, or the first day of January, the equation is nothing in those days.

A still greater inequality, in the measure of time, is produced by the obliquity of the equator to the plane of the ecliptic. The vernal equinox happens about the 21st of March; the autumnal, the 23d of September; the summer solstice, about the 21st of June; the winter, the 22d of December. From either equinox to the succeeding solstice, the Sun, on account of the obliquity, would be faster than the clock. From a solstice to an equinox, it would be slower than the clock. When greatest, this equation is about $9' 54''$.

To render this familiar, let a wire be bent into a circle, to represent the Earth's orbit; let it be marked into equal spaces or arches, to show the daily motion of the Earth in its orbit. It is not essential that these spaces or arches should be degrees, or exactly so far as the Earth moves in a day, but any convenient distance. In or near the centre of the wire, let a lamp be suspended, in the middle of a large room or hall, to represent the Sun. Let a small globe be holden at a distance from the floor equal to that of the lamp, and on the west side of it, the axis perpendicular to the floor. Keeping the globe in this position, let it be moved upwards, and turned on its axis so as to perform one rotation in the time of its moving one space on the wire or supposed orbit. Both motions being kept equable, and the globe being moved completely round the lamp, it will be found that any meridian of the globe will perform a revolution, and come round to the lamp in the same time that the globe moves one arch of the wire, in all parts of it, except two points, when it is directly over and directly under the lamp. In those points, a meridi-

an must move once and a half round, in order to come to the lamp. The motion of the globe from one mark to another on the wire, may represent a solar or natural day; a rotation on the axis, the sidereal day; the two points where the globe must be turned once and a half round, the summer and winter solstices. Were the axis of the Earth in the position in which that of the globe is supposed, it would coincide with the plane of the ecliptic, and the solar and sidereal days would be equal throughout the year, except at the solstitial points, where, as in the hypothesis, the solar day would be equal to one and a half sidereal days.

Let the axis of the globe be placed perpendicular to the plane of the wire, or supposed orbit, carried up, and turned round as in the former case. It will be found, that a meridian, which was towards the lamp at the commencement of a revolution, on the axis of the globe, will not, by being turned once round, be brought to the lamp again, but must, in every part of the supposed orbit, be turned a little farther, or more than once round, before it will become opposite to the lamp. It will also be found, that, if the spaces or arches on the wire, or supposed orbit, be marked as in the former supposition, and a revolution on the axis of the globe be completed in each of these, an additional turn will be requisite to bring a meridian round to the lamp, and that the differences will be equal in the whole revolution round the supposed orbit; and that, if the spaces, in which a revolution on the axis is completed, be taken to represent sidereal days, in the annual revolution of the Earth, an addition must be made to each of these spaces, in order that they may represent solar days.

A still different position of the globe may be conceived, in which the axis may be placed obliquely to the plane of the supposed orbit. In this case, the differences would not be at two points, as in one of the

above suppositions, nor equable, as in the other; but longer at those points, and shorter farther distant, the less the inclination of the axis to the plane of the supposed orbit. A position may be taken which would be a true representation of the Earth in its different motions. In such a position, the axis of the globe would be inclined to the axis of its supposed orbit in an angle of about $23^{\circ} 28'$. From this, it would appear, that the differences of the days are not wholly at the solstices, nor equable throughout the annual revolution, but are longer at the solstices, and shorter at the equinoxes, than the true solar days.

The common mode of explaining this equation by a supposed *real* and *fictitious* Sun, is on the principle of the Ptolemaic system, and gives no consistent idea concerning the cause of this equation.

The following table shows the difference between a true time-keeper and the Sun for every day in the year. To prevent an error from bissextile, it is calculated for four years. Altered from European tables, it corresponds to the time at Washington, and will answer, without essential error, in any part of the United States.

Is the apparent motion of the Sun an exact measure of time? At how many times in a year does the Sun coincide with a good clock in the measure of time? What are those times? When is the Sun fast and when slow of the clock? At what time is the greatest difference between the Sun and the clock? How much is the difference? What causes the difference between the Sun and a well-regulated clock? How do you account for the equation arising from the elliptical figure of the Earth's orbit? By this equation, when would the Sun be faster and when slower than a clock? What is the greatest difference arising from this equation? When is the Earth in the aphelion and when in the perihelion of its orbit? When is the vernal and when the autumnal equinox? When is the summer and when the winter solstice? When, on account of the obliquity of the equator to the ecliptic, would the Sun be faster and when slower than the clock? What is the greatest equation arising from this cause? How can you, by a familiar representation, explain the principles on which this equation is founded? What objection can be made to the common mode of explaining this equation?

EQUATION OF TIME.

The Sun faster or slower than the clock.

BISSEXTILE.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	8	14	4	12	27	3	38	3	13	2	28
2	4	36	14	11	12	14	3	20	3	20	2	18
3	5	4	14	17	12	1	3	2	3	27	2	9
4	5	31	14	23	11	47	2	44	3	33	1	59
5	5	58	14	28	11	32	2	26	3	38	1	49
6	6	25	14	32	11	18	2	9	3	43	1	38
7	6	50	14	35	11	3	1	51	3	47	1	27
8	7	15	14	37	10	47	1	34	3	51	1	15
9	7	40	14	38	10	31	1	17	3	53	1	3
10	8	5	14	39	10	15	1	1	3	55	0	51
11	8	29	14	39	9	58	0	45	3	57	0	39
12	8	52	14	38	9	41	0	29	3	59	0	27
13	9	15	14	37	9	24	0	14	4	0	0	15
14	9	36	14	34	9	7	0	2	4	0	0	2
15	9	57	14	31	8	50	0	16	3	59	0	11
16	10	18	14	27	8	32	0	31	3	58	0	24
17	10	38	14	23	8	14	0	45	3	56	0	36
18	10	57	14	18	7	56	0	59	3	53	0	49
19	11	16	14	12	7	38	1	12	3	50	1	2
20	11	34	14	6	7	20	1	25	3	47	1	16
21	11	50	13	58	7	2	1	37	3	43	1	29
22	12	6	13	50	6	43	1	48	3	39	1	42
23	12	22	13	42	6	25	1	59	3	34	1	55
24	12	37	13	33	6	6	2	10	3	29	2	8
25	12	51	13	24	5	48	2	21	3	23	2	20
26	13	4	13	14	5	29	2	31	3	16	2	33
27	13	16	13	3	5	11	2	41	3	9	2	45
28	13	27	12	51	4	52	2	50	3	1	2	57
29	13	38	12	39	4	33	2	58	2	53	3	9
30	13	48			4	15	3	6	2	45	3	20
31	13	57			3	56			2	38		

EQUATION OF TIME.

The Sun faster or slower than the clock.

BISSEXTILE.

Days.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	31	5	50	0	34	10	42	16	15	10	12
2	3	42	5	46	0	53	11	1	16	15	9	48
3	3	53	5	41	1	12	11	19	16	15	9	24
4	4	3	5	35	1	32	11	37	16	13	8	59
5	4	14	5	29	1	52	11	55	16	10	8	33
6	4	24	5	22	2	12	12	12	16	6	8	7
7	4	33	5	14	2	32	12	28	16	2	7	41
8	4	42	5	6	2	52	12	44	15	57	7	14
9	4	51	4	58	3	13	12	59	15	51	6	46
10	4	58	4	49	3	34	13	15	15	44	6	19
11	5	7	4	39	3	54	13	30	15	36	5	51
12	5	14	4	29	4	15	13	44	15	27	5	22
13	5	21	4	19	4	36	13	58	15	18	4	53
14	5	27	4	7	4	57	14	11	15	8	4	24
15	5	33	3	55	5	18	14	23	14	56	3	54
16	5	39	3	43	5	39	14	35	14	44	3	25
17	5	44	3	30	6	0	14	47	14	31	2	55
18	5	49	3	17	6	20	14	56	14	18	2	25
19	5	53	3	3	6	41	15	7	14	4	1	55
20	5	57	2	49	7	2	15	16	13	49	1	25
21	5	59	2	35	7	23	15	25	13	32	0	55
22	6	1	2	20	7	44	15	33	13	15	0	25
23	6	3	2	4	8	4	15	40	12	58	0	5
24	6	4	1	48	8	24	15	47	12	40	0	35
25	6	4	1	31	8	45	15	53	12	21	1	5
26	6	4	1	14	9	5	15	59	12	1	1	35
27	6	4	0	57	9	25	16	4	11	41	2	4
28	6	2	0	40	9	45	16	8	11	19	2	33
29	6	0	0	22	10	4	16	10	10	57	3	2
30	5	57	0	4	10	23	16	12	10	35	3	31
31	5	54	0	* 15			16	14			4	0

EQUATION OF TIME.

The Sun faster or slower than the clock.

FIRST AFTER BISSEXTILE.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	29	14	10	12	30	3	43	3	12	2	31
2	4	57	14	17	12	17	3	25	3	19	2	22
3	5	14	14	22	12	4	3	6	3	26	2	12
4	5	52	14	27	11	51	2	48	3	32	2	2
5	6	19	14	32	11	37	2	31	3	37	1	52
6	6	44	14	35	11	22	2	13	3	42	1	41
7	7	9	14	37	11	7	1	56	3	46	1	31
8	7	35	14	39	10	52	1	39	3	50	1	19
9	7	59	14	40	10	36	1	22	3	53	1	7
10	8	23	14	40	10	20	1	5	3	55	0	55
11	8	46	14	39	10	3	0	49	3	57	0	43
12	9	9	14	38	9	46	0	33	3	59	0	31
13	9	31	14	35	9	29	0	17	4	0	0	19
14	9	52	14	32	9	12	0	2	4	0	0	7
15	10	13	14	28	8	54	0	* 13	4	0	0	* 6
16	10	33	14	24	8	37	0	28	3	59	0	19
17	10	52	14	19	8	19	0	42	3	58	0	32
18	11	11	14	14	8	1	0	56	3	55	0	45
19	11	29	14	8	7	43	1	9	3	52	0	58
20	11	46	14	0	7	25	1	22	3	49	1	11
21	12	2	13	52	7	6	1	35	3	46	1	24
22	12	18	13	44	6	48	1	47	3	41	1	37
23	12	33	13	35	6	29	1	58	3	37	1	50
24	12	47	13	26	6	11	2	9	3	31	2	3
25	13	1	13	16	5	52	2	19	3	25	2	16
26	13	13	13	6	5	34	2	30	3	19	2	28
27	13	24	12	54	5	15	2	39	3	12	2	41
28	13	35	12	42	4	56	2	48	3	4	2	53
29	13	45			4	38	2	57	2	56	3	5
30	13	54			4	19	3	5	2	48	3	17
31	14	3			4	1			2	40		

EQUATION OF TIME.

EQUATION OF TIME.

The Sun faster or slower than the clock.

FIRST AFTER BISSEXTILE.

Days.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	28	5	51	0	28	10	36	16	14	10	17
2	3	39	5	47	0	0	10	55	16	14	9	54
3	3	50	5	42	1	1	11	13	16	13	9	30
4	4	0	5	37	1	1	11	31	16	12	9	5
5	4	11	5	31	1	46	11	49	16	9	8	39
6	4	21	5	24	2	6	12	6	16	6	8	13
7	4	30	5	16	2	26	12	22	16	2	7	47
8	4	39	5	8	2	46	12	38	15	58	7	20
9	4	48	5	0	3	7	12	54	15	52	6	53
10	4	57	4	51	3	27	13	10	15	45	6	25
11	5	4	4	42	3	48	13	25	15	37	5	57
12	5	11	4	32	4	9	13	39	15	29	5	29
13	5	18	4	22	4	30	13	53	15	20	5	0
14	5	25	4	10	4	51	14	6	15	10	4	31
15	5	31	3	58	5	12	14	19	14	59	4	2
16	5	37	3	46	5	33	14	31	14	47	3	32
17	5	42	3	34	5	54	14	42	14	34	3	3
18	5	47	3	21	6	14	14	53	14	21	2	33
19	5	51	3	7	6	35	15	3	14	7	2	3
20	5	55	2	53	6	56	15	13	13	52	1	33
21	5	58	2	39	7	17	15	22	13	36	1	3
22	6	0	2	24	7	37	15	30	13	19	0	32
23	6	2	2	9	7	58	15	37	13	2	0	2
24	6	3	1	53	8	18	15	44	12	44	0	28
25	6	4	1	36	8	39	15	51	12	25	0	58
26	6	4	1	19	8	59	15	56	12	5	1	28
27	6	4	1	2	9	19	16	1	11	45	1	57
28	6	3	0	45	9	38	16	5	11	24	2	26
29	6	1	0	27	9	58	16	9	11	2	2	56
30	5	58	0	9	10	17	16	11	10	40	3	25
31	5	55	0	9			16	13			3	53

EQUATION OF TIME.

The Sun faster or slower than the clock.

SECOND AFTER BISSEXTILE.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	21	14	7	12	32	3	46	3	11	2	34
2	4	49	14	14	12	20	3	28	3	18	2	25
3	5	17	14	20	12	6	3	10	3	25	2	15
4	5	44	14	25	11	53	2	52	3	31	2	6
5	6	11	14	29	11	39	2	34	3	37	1	55
6	6	37	14	33	11	24	2	16	3	42	1	45
7	7	2	14	35	11	10	1	59	3	46	1	34
8	7	27	14	37	10	55	1	42	3	50	1	22
9	7	52	14	39	10	39	1	25	3	53	1	10
10	8	16	14	39	10	23	1	9	3	55	0	58
11	8	40	14	39	10	7	0	53	3	57	0	46
12	9	3	14	38	9	50	0	37	3	59	0	34
13	9	26	14	36	9	33	0	21	4	0	0	21
14	9	47	14	33	9	16	0	6	4	0	0	9
15	10	8	14	30	8	59	0	9	4	0	0	4
16	10	28	14	26	8	41	0	24	3	59	0	17
17	10	48	14	21	8	23	0	38	3	58	0	30
18	11	7	14	16	8	6	0	52	3	55	0	43
19	11	26	14	10	7	48	1	5	3	52	0	56
20	11	43	14	3	7	30	1	18	3	49	1	9
21	11	59	13	55	7	11	1	31	3	46	1	22
22	12	15	13	47	6	53	1	43	3	42	1	35
23	12	30	13	38	6	34	1	55	3	37	1	47
24	12	44	13	29	6	16	2	6	3	32	2	0
25	12	58	13	19	5	57	2	17	3	27	2	13
26	13	10	13	8	5	38	2	27	3	21	2	25
27	13	21	12	56	5	19	2	37	3	14	2	37
28	13	32	12	44	5	1	2	47	3	7	2	49
29	13	42			4	42	2	56	2	59	3	1
30	13	52			4	23	3	4	2	51	3	13
31	14	0			4	5			2	43		

EQUATION OF TIME.

The Sun faster or slower than the clock.

SECOND AFTER BISSEXTILE.

Days.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	24	5	52	0	24	10	32	16	14	10	23
2	3	35	5	48	0	43	10	50	16	14	9	59
3	3	46	5	43	1	2	11	9	16	14	9	35
4	3	57	5	36	1	21	11	27	16	12	9	11
5	4	7	5	32	1	41	11	44	16	9	8	45
6	4	18	5	26	2	0	12	1	16	6	8	19
7	4	28	5	19	2	20	12	17	16	2	7	53
8	4	37	5	11	2	41	12	33	15	58	7	26
9	4	46	5	3	3	1	12	49	15	52	6	59
10	4	55	4	54	3	21	13	5	15	46	6	31
11	5	3	4	45	3	42	13	20	15	38	6	3
12	5	11	4	35	4	3	13	34	15	30	5	35
13	5	18	4	25	4	23	13	48	15	21	5	6
14	5	25	4	14	4	44	14	2	15	11	4	37
15	5	31	4	2	5	5	14	15	15	1	4	8
16	5	37	3	50	5	26	14	27	14	49	3	39
17	5	42	3	38	5	47	14	38	14	37	3	9
18	5	47	3	25	6	8	14	49	14	24	2	40
19	5	51	3	12	6	29	15	0	14	10	2	10
20	5	55	2	58	6	50	15	10	13	55	1	40
21	5	58	2	43	7	11	15	20	13	40	1	10
22	6	0	2	28	7	32	15	28	13	23	0	40
23	6	2	2	13	7	53	15	36	13	6	0	10
24	6	3	1	57	8	13	15	43	12	48	0	* 20
25	6	4	1	40	8	34	15	50	12	30	0	50
26	6	4	1	23	8	54	15	55	12	11	1	19
27	6	3	1	6	9	14	16	0	11	51	1	49
28	6	2	0	49	9	34	16	5	11	30	2	18
29	6	1	0	31	9	53	16	9	11	8	2	48
30	5	58	0	13	10	13	16	11	10	46	3	17
31	5	55	0	* 5			16	12			3	clock 46

EQUATION OF TIME.

The Sun faster or slower than the clock.

THIRD AFTER BISSEXTILE.

Days.	Jan.		Feb.		March.		April.		May.		June.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	4	14	14	5	12	35	3	51	3	9	2	36
2	4	42	14	12	12	22	3	32	3	16	2	27
3	5	10	14	18	12	9	3	14	3	23	2	17
4	5	38	14	24	11	56	2	56	3	29	2	7
5	6	5	14	29	11	42	2	39	3	35	1	57
6	6	31	14	33	11	28	2	21	3	40	1	46
7	6	57	14	35	11	14	2	4	3	44	1	35
8	7	22	14	37	10	59	1	47	3	48	1	24
9	7	47	14	39	10	43	1	30	3	52	1	12
10	8	11	14	40	10	27	1	14	3	54	1	0
11	8	35	14	40	10	11	0	58	3	56	0	48
12	8	58	14	39	9	54	0	42	3	58	0	36
13	9	21	14	37	9	37	0	26	3	59	0	24
14	9	42	14	34	9	20	0	10	4	0	0	12
15	10	3	14	30	9	3	0	5	4	0	0	1
16	10	24	14	26	8	45	0	20	3	59	0	13
17	10	43	14	22	8	28	0	35	3	58	0	26
18	11	2	14	16	8	10	0	49	3	56	0	39
19	11	20	14	10	7	52	1	3	3	54	0	52
20	11	38	14	3	7	33	1	16	3	51	1	5
21	11	54	13	55	7	15	1	29	3	48	1	17
22	12	10	13	47	6	56	1	41	3	44	1	30
23	12	25	13	39	6	38	1	53	3	39	1	43
24	12	39	13	30	6	19	2	4	3	34	1	56
25	12	53	13	20	6	0	2	15	3	29	2	9
26	13	6	13	10	5	42	2	25	3	23	2	21
27	13	17	12	59	5	23	2	35	3	16	2	34
28	13	28	12	47	5	4	2	45	3	9	2	46
29	13	39			4	46	2	54	3	1	2	59
30	13	49			4	27	3	2	2	53	3	11
31	13	58			4	9			2	45		

EQUATION OF TIME.

The Sun faster or slower than the clock.

THIRD AFTER BISSEXTILE.

Days.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
1	3	22	5	53	0	19	10	27	16	13	10	28
2	3	33	5	49	0	38	10	46	16	14	10	5
3	3	44	5	45	0	57	11	4	16	14	9	41
4	3	55	5	40	1	16	11	22	16	13	9	17
5	4	6	5	34	1	36	11	40	16	10	8	51
6	4	16	5	28	1	55	11	57	16	7	8	25
7	4	26	5	21	2	15	12	14	16	4	7	59
8	4	36	5	13	2	36	12	30	16	0	7	33
9	4	45	5	5	2	56	12	46	15	54	7	6
10	4	54	4	56	3	17	13	2	15	48	6	39
11	5	2	4	47	3	38	13	17	15	41	6	11
12	5	9	4	38	3	58	13	32	15	33	5	43
13	5	16	4	27	4	19	13	46	15	25	5	14
14	5	23	4	16	4	40	14	0	15	15	4	46
15	5	29	4	4	5	1	14	13	15	5	4	17
16	5	35	3	52	5	23	14	26	14	53	3	48
17	5	40	3	40	5	44	14	37	14	41	3	18
18	5	45	3	27	6	5	14	48	14	28	2	48
19	5	49	3	14	6	26	14	59	14	15	2	18
20	5	53	3	0	6	47	15	9	14	0	1	48
21	5	56	2	45	7	8	15	19	13	45	1	18
22	5	58	2	31	7	28	15	27	13	28	0	48
23	6	0	2	16	7	49	15	35	13	11	0	18
24	6	2	2	0	8	9	15	42	12	53	0	* 12
25	6	3	1	44	8	29	15	49	12	35	0	42
26	6	3	1	27	8	50	15	54	12	16	1	12
27	6	3	1	10	9	10	16	0	11	56	1	42
28	6	2	0	53	9	29	16	4	11	35	2	12
29	6	1	0	35	9	49	16	8	11	13	2	41
30	5	59	0	18	10	8	16	10	10	51	3	11
31	5	56	0	* 0			16	12			3	40

CHAPTER VI.

The Harvest Moon.

THE Moon moves in her orbit ($13^{\circ} 10' 35''$) in each solar day of 24 hours. But as the motion of the Earth in the ecliptic, at the same time, is $59' 8''$, the apparent motion of the Sun, the excess of her motion over that of the Earth, or the Sun's apparent motion, is ($12^{\circ} 11' 27''$). A meridian of the Earth, in its diurnal rotation, moves this in $48' 38''$ of time. But, the Moon at the same time moving forward, the meridian will not overtake her till $50' 28''$. The Moon rises at the equator, therefore, about ($50' 28''$) later on each succeeding day, than it did on the preceding, at all seasons of the year. But the case is very different in high latitudes. Farmers in those latitudes have long observed (the early rising of the autumnal full moon.) "In this instance," says Mr. Ferguson, "as in many others, discoverable by astronomy, the wisdom and beneficence of the Deity are conspicuous, who ordered the Moon so as to bestow more or less light on all parts of the Earth, as their several circumstances and seasons render it more or less serviceable. About the equator, where there is no variety of seasons, and the weather changes seldom, and at stated times, moonlight is not necessary for gathering in the produce of the ground; and there the Moon rises about 50 minutes later every day or night than on the former. In considerable distances from the equator, where the weather and seasons are more uncertain, the autumnal full Moons rise very soon after sunset for several evenings together. At the polar circles, where the mild season is of short duration, the autumnal full Moon rises at sunset from the first to the third quarter."

The horizon of any place forms angles with the plane

of the Moon's orbit, differing from each other at different parts of the day, and at different seasons of the year. From the (varied position of these circles) arise the phenomena of the harvest Moon. About the (23d of September,) when the Sun enters Libra, the Earth enters Aries. At any place in north latitude, the angle between the horizon and the Moon's orbit is less, at that season of the year, about the time of sunset, than at any other time of the day. The full Moon, about the autumnal equinox, being in that part of her orbit opposite the Sun, must rise at this angle in latitudes below the Arctic circle. The angle decreases from the equator to this circle, where it vanishes. While the Moon remains in this part of her orbit, in all places where the angle is small, her diurnal motion will make but little variation in the time of day when she rises, on each succeeding evening.

To illustrate the phenomena of the harvest Moon, (put small pieces of paper on the ecliptic of a terrestrial globe, on each side of the first degree of Aries, at $12^{\circ} 11' 27''$ from each other, representing the Moon's diurnal motion from the Sun; rectify the globe for the latitude of the place, suppose 45° . With the number of papers or pieces of paper corresponding to the days of a week, bring the westernmost to the eastern horizon; set the index of the hour circle at the time of the Moon's rising, on the evening nearest to three and a half days before her arrival at the first degree of Aries. Turn the globe westward, which will be the same in effect as the rotation of the horizon eastward in respect to the Moon, till the second paper is brought to the horizon; the index will point to the time of the Moon's rising on the succeeding evening. Bring in succession the papers to the horizon; the index will show the time of the Moon's rising on the succeeding days of the week. The inclination of the Moon's orbit to the plane of the ecliptic will not materially affect this representation.

When the full happens at the equinox, the Moon ar-

rives at the first of Aries at that time. But when the full nearest the equinox happens any number of days before or after the 23d of September, her distance from that point at the full may be obtained with sufficient nearness, by taking a degree for each day between the full and the equinox, rejecting odd minutes both of time and motion. Compute the time of her arrival by her motion from the Sun. It will be found that the Moon is rarely more than one day's motion from the first of Aries at the time of the equinoctial full.

If the index be set at 12, when the first paper is brought to the horizon, and the other papers be brought in succession to that circle, the difference of time, when the Moon rises on the several nights, may be seen on the hour circle.

A more natural representation of the harvest Moon may be made by an artificial globe taken from the frame. Let a candle be placed on a stand, to represent the Sun. On a level with the candle, and a little distance to the west of it, let the globe be holden, the north pole so elevated as to form an angle of $23^{\circ} 28'$ with the horizon. Let a small taper be placed under the globe, to represent the Moon at her first quarter. Carried to the west of the globe, the taper may represent her at the full in Aries. Over the globe, it will show her situation at her last quarter. By turning the globe round, and observing when any place, as Washington, comes into the light of the taper in its different situations, the appearance of the Moon rising at that place may be represented. If, in its western position, the taper be moved slowly and circularly up, so that the arch moved may subtend an angle of $12\frac{1}{2}^{\circ}$ at the globe, while the globe itself is turned once round on its axis, and continued in this manner for several rotations, nearly an exact resemblance of the harvest Moon may be presented.

When the Moon rises with the least angle, she sets with the greatest; and when she rises with the great-

est, she sets with the least. In other words, when the time of day, in which she rises for successive evenings, differs the least, the time of day in which she sets differs the most. At the full, the time of rising on successive evenings, differs most about the vernal equinox.

In every revolution, the Moon passes through the same signs; but, except in autumn, her rising with the least angle or difference of time, always about the first of Aries, is seldom observed. She enters Aries, in winter, about the first quarter, and, rising about midday, attracts no particular notice; about the change in spring, when, from nearness to the Sun, she is not visible; in summer, about the last quarter, and rising at or near midnight, is seldom observed.

The statement of Mr. Ferguson, respecting the rising of the Moon at the polar circles, is not strictly true. From the first quarter, when she rises about sunset at those circles, to nearly the last quarter, the Moon rises 3 m. 56 s. earlier in the day on each succeeding evening.

The Moon is seldom full exactly at the equinox. When it is not, the fulls immediately before and after that time, exhibit phenomena resembling the equinoctial full. The nearer any full is to the equinox, the more resemblance it bears to the harvest Moon; the nearest being generally so denominated, whether it happen before or after the equinox.

The same phenomena are exhibited by the Moon in south latitudes, but at opposite times of the year; the autumnal equinox of south latitude being coincident with the vernal of the north.

The circumstances of the harvest Moon are in some measure affected by the inclination of the Moon's orbit to the ecliptic. This inclination is about $5^{\circ} 9'$. Moving backward, her nodes perform a revolution in about 18 y. 224 d. The harvest Moon is most beneficial during half of this time; least beneficial during the other half; most, when her ascending node is in the first

degree of Aries ; least, when her descending node is in that degree.

The full Moon, in summer, always runs low, but much lower in some years than in others. The running low seldom attracts particular notice, except when she is in that part of her orbit which is south of the ecliptic. The summer full Moon runs the lowest, when her latitude south is greatest ; or she is 90° from her nodes. When the Moon is north of the ecliptic, she runs high at the winter fulls ; highest, when she is farthest north, or 90° from her nodes. The full Moons of summer not only run low, but continue a short time above the horizon. But this is at the time when the length of the days makes moonlight of little utility. On the contrary, the full Moons of winter not only run high, but continue long above the horizon. This is at the season when the light of the Moon is peculiarly useful, guiding and cheering the lonely traveller in the dreary and protracted nights.

At the poles, the full Moon, being below the horizon, is not seen for nearly half the year. This is in summer, when, were the Moon to shine, her light, immersed in the continued splendor of the Sun, would be of no use. In winter, when, at the benighted polar regions, the light of the Moon is most beneficial, she shines from about the first to the third quarter. What claim can he have to rational being, who does not admire and adore the wisdom and benevolence of Him, who not only "*gave the Sun for a light by day,*" but "*the Moon and Stars for a light by night !*"

The years, when the harvest Moon is least, and when most beneficial, may be seen in the following table. L. stands over the columns least beneficial ; M. over those most beneficial. In both the columns marked N., the harvest Moon is farthest north in the orbit ; in those marked S., it is farthest south.

HARVEST MOON OF THE NINETEENTH CENTURY.

Years least beneficial.

N.	L.								S.
1806	1807	1808	1809	1810	1811	1812	1813	1814	1815
1825	1826	1827	1828	1829	1830	1831	1832	1833	
1844	1845	1846	1847	1848	1849	1850	1851	1852	
1862	1863	1864	1865	1866	1867	1868	1869	1870	
1881	1882	1883	1884	1885	1886	1887	1888	1889	
1899	1900								

Years most beneficial.

S.				M.					N.	
				1801	1802	1803	1804	1805		
1816	1817	1818	1819	1820	1821	1822	1823	1824		
1834	1835	1836	1837	1838	1839	1840	1841	1842	1843	
1853	1854	1855	1856	1857	1858	1859	1860	1861		
1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	
1890	1891	1892	1893	1894	1895	1896	1897	1898		

How far does the Moon move in a solar day? How much does the motion of the Moon exceed the apparent motion of the Sun? At the equator, what is the difference in the time when the Moon rises on each succeeding night? In high latitudes, what have farmers observed respecting the rising of the autumnal full Moon? What is there remarkable in the Moon's rising at the polar circles? From what arise the phenomena of the harvest Moon? When is the harvest Moon? How would you illustrate the phenomena of the harvest Moon? What would give a very natural representation of this peculiarity in the Moon's rising? When there is the least difference in the time of the Moon's rising, how is her setting? As the Moon passes through the same signs in every revolution, why are not the phenomena of the harvest Moon observed at other seasons besides autumn? Why is not the statement of Mr. Ferguson respecting the Moon's rising at the polar circles, strictly true? When the Moon is not full exactly at the equinox, what fulls are

taken for the harvest Moon? When have the inhabitants of south latitude the phenomena of the harvest Moon? Does the inclination of the Moon's orbit to the ecliptic affect the phenomena of the harvest Moon? Is the motion of the Moon's nodes direct or retrograde? How long are they in performing a revolution? During what part of the time of their revolution is the harvest Moon most beneficial, and what part least beneficial? When does the full Moon run low? In what part of her orbit does it run lowest? How are the full Moons of winter? When do they run highest? Is the regulation of the high and low fulls calculated for our benefit? How long does the Moon shine in winter in the polar regions? Do the wisdom and benevolence of the Deity appear in the regulations of the Moon?

CHAPTER VII.

The Tides.

THE tides are the alternate ebbing and flowing of the sea. They are imperceptible in the midst of the ocean, and can only be known by the rising of the water on the adjacent land, or where the depth of water will admit of sounding.

{ Kepler } was the first who discovered the true cause of the tides, and that the attraction of the Sun and Moon produced the constant flux and reflux of the water. But, a "hint being given, the immortal { Sir Isaac Newton } improved it, and wrote so amply on the subject, as to make the theory of the tides in a manner quite his own, by discovering the cause of their rising on the side of the Earth opposite to the Moon. For Kepler believed that the presence of the Moon occasioned an impulse, which caused another in her absence."

The attraction of the Moon is the principal cause of the tides; but the attraction of the Sun operates to in-

crease or diminish the height or depression of the water occasioned by the lunar attraction. But, were every part of the Earth equally attracted by the heavenly bodies, (no tide could be produced.) The unequal attraction, or the attraction of one part of the terraqueous globe more forcibly than the other, may be considered as the true cause of the tides. The force of attraction in any body decreases, as the squares of the distances from that body increase. Hence the farther distant any body is from the centre of attraction, the less the operation on that body. The water, therefore, on the side of the Earth next to the Moon, is more forcibly attracted than the body of the Earth, and the body of the Earth than the water on the opposite side. Suppose three particles of matter, one on the surface of the Earth next to the Moon, one at the centre of the Earth, and one on the surface opposite to the Moon. By the laws of gravitation, the particle nearest to the Moon would be more attracted by her, than that at the centre, and that at the centre more attracted than the particle on the opposite side. By the unequal attractions, the distances between these particles would be increased. One would be elevated from the centre, and the centre particle would be drawn from that on the side opposite to the Moon, amounting to the same thing as if the opposite particle were elevated. For, when the distance between the centre of the Earth and a particle at the surface is increased, the particle will appear raised from the surface. We take notice of a tide, because the water rises on the adjacent land. This will be the case when the distance between the surface of the water and the centre of the Earth is increased, whether the water be elevated from the Earth, or the Earth be withdrawn from the water. No more difficulty, therefore, arises in accounting for the tide on the side of the Earth opposite the Moon, than for that on the surface nearest to her, both being the effect of unequal attraction.

The points directly under and opposite to the Moon,

may be considered as the centres of highest elevation ; and 90° from these, or half the distance between them, as the circle of low water. This extends wholly round the Earth, and moves as the Moon moves.

Let N E O E be the Earth, (Plate vi. Fig. 3,) C the centre ; M the Moon ; N the point on the Earth's surface next to the Moon ; O a point on the opposite surface ; E E the circle of low water. The attraction of the Moon, M, being unequal at the different parts, from the circle E E, the water on the side next to the Moon is more attracted than the centre, C, where the solid body of the Earth may be considered as concentrated ; and the centre, C, more attracted than the water on the opposite side. The water, therefore, will rise at N, increasing the distance from the centre, C. On the same principle, C, the centre, and with it the mass of the Earth, will be attracted from the surface at O, enlarging the distance, and leaving the water, which, being farther from the centre, is higher to the observer ; high and low, in respect to the Earth, always relating to the distance from the centre.

Some have accounted for the tide on the side of the Earth opposite to the Moon (by the motion of the Earth and Moon round a common centre.) In the revolution of these bodies, the side of the Earth farthest distant from the Moon must have a swifter motion than the side nearest to her. The water, endeavoring to escape, must rise towards the highest part, the point opposite to the Moon. Some effect may be attributed to this ; but, without doubt, the unequal attraction is the principal cause.

The tides, travelling as the Moon travels, (have her declination) and the declination opposite. As the Moon revolves round the Earth, they revolve, following her in her perpetual motion. Below the polar circles, therefore, every place, in its diurnal rotation, must have two tides in about (24 h. 50 m. 28 s.)

When the Moon is in the equator, the circle of low

water, 90° distant, must extend from pole to pole.) Every place, from the equator to the poles, must have its regular return of tides; and these, uninfluenced by extraneous causes, must return at equal intervals.

7 As the Moon moves from the equator towards either tropic, the circle of low water recedes from the poles towards the polar circles, arriving at these when she arrives at the tropics. (Plate vi. Fig. 4 and 5.)

This departure of the Moon from the equator must make flood tide at the poles, increasing as her declination increases, and highest when she is farthest distant from the equator. On her return, the tides ebb at the poles; where it becomes low water, when she arrives at the equinoctial. In a revolution of the Moon, therefore, two tides only occur at the poles, full sea returning at intervals of about $13\frac{1}{2}$ days. During the interval in which the circle of low water is distant from the poles, places in any parallel, touching the highest point of that circle, have but one tide, in a revolution from the Moon round to the Moon again. Places between that circle and the poles, in the same time, have but one, and that a partial tide; while all below its highest point have two tides in succession.

At the equator, the intervals between high and low water, or between a tide and a succeeding tide, remain equal, whatever may be the declination of the Moon. When she is in the equator, the tides return at equal intervals in all latitudes. But when she is in any degree of declination, places on each side of the equator, cutting the circle of low water in their diurnal rotation, or which are below the highest point of ebb tide, have unequal duration of ebb and flood, or of time between high and low water, in different parts of the lunar day; the farther distant from the equator, the more unequal the returns.

The Moon being in her north declination, places in the northern hemisphere have their highest tides when she is above the horizon, (Plate vi. Fig. 5;) but when

she is in south declination, the opposite tides the highest. (Plate vi. Fig. 4.) In the southern hemisphere, the whole is reversed.

The tide, as raised by the Moon, is greater on the side of the Earth (next to her) than that on the opposite side. The cause of this is apparent. For, as she is nearer to that side, the semi-diameter of the Earth bears the greater proportion to the shorter distance.

For convenience of explication, the highest tides have been considered directly under and opposite the Moon. It is, however, learned from observation, that the tide is not at its greatest height above or below the horizon, till after the Moon has passed the meridian; because the water, having obtained a direction, continues that direction after the Moon has passed, till prevented by external force. Similar occurrences are common. (The heat of the day is most intense after the Sun has passed the meridian; and the extreme of summer heat is generally not till some time after the summer solstice.)

The tides are in some measure altered by the inclination of the Moon's orbit to the plane of the ecliptic. Hence the highest elevation of water may at times be more than 5° above the tropics; and the region of single tide reduced as much below the polar circles.

The tides, as we have seen, are affected by the influence of the Sun. The attraction of the Sun is more powerful at the Earth than that of the Moon, but has less effect in raising tides. (The immense distance of the Sun from the Earth, causes his attraction on the different parts to be nearly equal; the semi-diameter of the Earth bearing but a very small proportion to this immense distance. The influence of the Sun causes the tides to be earlier in the first and third quarters of the Moon; later in her second and fourth.) In the former case, the tide of the Moon is preceded by that of the Sun; in the latter, it is succeeded and retarded by the elevation of water raised by the Sun. The

highest tides) are denominated *spring tides*. These happen at the conjunctions and oppositions of the Sun and Moon, or at the changes and fulls. (Plate vi. Fig. 6.) *Neap tides*, so called, are the lowest. These are at the quadratures, or when the Moon is in her quarters. (Plate vi. Fig. 7.) The tides happening at the change and full, about the equinoxes, are higher than those of other seasons. (Both luminaries, being then in the equator,) have a greater influence upon the Earth, in respect to tides, than at other seasons. The equatorial diameter of the Earth being longer than any other, the attraction of the Moon and Sun on the different parts of the Earth is most disproportioned, when they are in the plane of the equator, or in the direction of that diameter. But the principal cause of unusual height in these tides, is, the centre of elevation in the water is at the equator, where the diurnal motion of the Earth is the greatest; and the tides, extending from pole to pole, are met directly by every part of the Earth's surface, in its diurnal rotation.

The Moon produces a higher tide when she is in perigee than when she is in apogee. The Sun also, being nearest to the Earth in winter, has his greatest influence on the tides at that season. The highest tides known are those happening a little before the vernal equinox, and a little after the autumnal equinox, when the Moon is in perigee; there being then a concurrence of all the causes which operate in the production of tides.

Small seas, unconnected with the ocean and lakes, have not sufficient extent of water for perceptible tides. The Baltic and the Mediterranean communicate with the ocean; but are too small in themselves, and have straits too narrow to admit an influx of water sufficient for tides of any considerable height.

The regular return of the tides, according to the motions of the Moon, is greatly interrupted. Incidents external vary the height of the tides, and the time of

their return in different places. They are affected by straits and shoals, islands and continents, channels, winds, and a variety of other causes, so that many hours intervene between the time of high water at one place and at another on the same coast. These may be considered exceptions to the general principles in the preceding theory.

The following remarks of Mr. Ferguson may be added, as worthy of much consideration: "It is not to be doubted, but that the Earth's quick rotation brings the poles of the tides nearer to the poles of the world, than they would be if the Earth were at rest, and the Moon revolved about it only once in a month; for, otherwise, the tides would be more unequal in their heights and times of their return, than we find they are. But however the Earth's rotation may bring the poles of its axis and those of the tides together, or how far the preceding tides may affect those which follow, so as to make them keep up nearly to the same heights and times of ebbing and flowing, is a problem more fit to be solved by observation than by theory." Notwithstanding the justness of these observations, it was thought every student of philosophic mind would wish to know the theory of the tides, as regulated by the influence of the great heavenly bodies.

The air, being a fluid, and extending much higher than the water, must be more affected by the unequal attraction of the Sun and Moon. Surrounding the whole Earth, and moving (without obstruction,) it must have tides more extensive, and generally higher, than those of the ocean.)

The tides are of vast utility. They benefit us in agriculture, and assist us in navigation.) The agitation they give to the water, together with saltness, prevents the ocean from becoming a vast reservoir of contagion and death. What infinite wisdom and goodness are displayed in giving such inconceivable power of benefiting us to bodies immensely distant!

What are the tides? How do we discover that there are tides? Who first discovered the true cause of the tides? Who wrote so amply on the tides as to make the theory of them in a measure his own? Who first discovered the true cause of the tide on the side of the Earth opposite to the Moon? If all parts of the Earth were equally attracted by the heavenly bodies, would there be tides? How is it that attraction causes a tide on the side of the Earth opposite to the Moon? Will the effect be the same, if the Earth be drawn away from the surface of the water, as if the water were drawn up on the land? How far is the circle of low water from the points of highest elevation in the tides? How far does this circle extend, and how does it move? How have some accounted for the tide on the side of the Earth opposite to the Moon? How do the tides travel? What declination have they? In what time does every place below the polar circles have two tides? When the Moon is in the equator, to what does the circle of low water extend? How must every place then have its return of tides? When does the circle of low water recede from the poles? How many tides occur at the poles in a revolution of the Moon? At the poles, how long is it between a tide and a succeeding tide? Where have places but one tide in a revolution from the Moon round to the Moon again? Where is the Moon, when the tides return at equal intervals in all latitudes? When the Moon is in any degree of declination, how do places distant from the equator, but below the circle of low water, have their return of tides? When does a place in north declination have a higher tide on the side of the Earth opposite to the Moon, than on the side next to her? Why is the point of highest elevation not directly under, but after the Moon? What other occurrences are similar to this? If the Sun attract the Earth more than the Moon, why does it not raise a higher tide? When does the influence of the Sun cause the tides to be earlier, and when later, than they would be by the attraction of the Moon? What are spring tides? When do they happen? What are neap tides, and when do they occur? Why are the tides happening at the change and full about the equinoxes higher than those of other seasons? At what time of year do the highest tides known happen? Why have small seas, unconnected with the ocean and lakes, no perceptible tides? What prevent the regular return of the tides, according to the motions of the Moon? What are Mr. Ferguson's remarks respecting the regularity of the tides? Have we reason to suppose there are tides in the air? Why may they be more extensive and high than those of the ocean? In what are the tides beneficial to us?

CHAPTER VIII.

Eclipses.

AN *eclipse* is a partial or total obscuration of a heavenly body.)

So far as astronomical observation has extended, the Sun is the only heavenly luminary in the solar system, that shines by its own light. The planets are in themselves opaque, and shine only by reflecting the solar rays. Hence on the side of these not illuminated by the Sun, dark shadows are cast. These shadows are in the form of vast cones extending into the heavens. They are but privations of light in the space hid from the Sun. (That they are not coextensive with the Sun's light, but terminate at a distance far more limited, is evident, because the primary planets never eclipse each other. Mars, though often in opposition to the Sun, is never eclipsed by the Earth's shadow. This must therefore terminate before it reaches that planet. (Plate vi. Fig. 8.) Let S be the Sun, A E the Earth, A B E the Earth's dark shadow, terminating at B. From this figure it is evident, that, when a luminous body is larger than a dark body, intercepting its rays, and causing a shadow, such shadow must end at the point where the rays from the extremes of the luminous body cross each other beyond the dark body; and that, as the Sun is far larger than the planets of our system, their shadows must terminate at points beyond the planets opposite to the Sun, at the intersection of the solar rays. The primary planets eclipse their secondaries, and the secondaries their primaries.) The Earth's shadow eclipses the Moon; the Moon's shadow the Earth. But, when the Earth is eclipsed by the Moon, the Sun is darkened to

some of the inhabitants of the Earth. Hence eclipses of the Earth are usually denominated *eclipses of the Sun*.

The shadow of the Earth, when longest, is about 219 of its semi-diameters.) Different computations make a trifling difference in the mean extent of this shadow. If the diameters of the Earth and Sun be taken as before stated, and the shadow be computed from these, it will be found to be about (217) semi-diameters of the Earth; equal to (864,094 miles).

If the Moon revolved in the plane of the ecliptic, an eclipse would happen at every conjunction and opposition, or at every change and full. (But, her orbit being inclined to that circle in an angle of $5^{\circ} 9' 3''$, varying a little at different times, eclipses cannot happen except when she is in or about her nodes.) In every other part of her orbit, she is either too far north or south to eclipse the Sun, or to fall into the Earth's shadow and be herself eclipsed. Plate vi. Fig. 11. represents the number of digits eclipsed up to 12 on the right hand, where the eclipse, being at the node, is total. The limit is different in different species of eclipses. For if the Moon be within about 17° of either of her nodes at the change, there will be a solar eclipse. But lunar eclipses can happen but when she is within about 11° of her nodes. The greatest limit in solar eclipses, according to the tables in the author's larger work, is $18^{\circ} 11'$, the least, $16^{\circ} 28'$; the greatest in lunar, $11^{\circ} 51'$, the least, $10^{\circ} 11'$.

(In lunar eclipses, when a part only of the Moon's disk is covered, the eclipse is denominated *partial*; when the whole disk is covered, *total*.) (when the centre of the disk passes through the centre of the shadow, *central*.) (Plate vi. Fig. 10.)

The Moon is visible, when totally immersed in the Earth's shadow, appearing of a dusky red color, like burnished copper. It is probable, that the refracted rays of the Sun cause this phenomenon. These, trav-

ersing the atmosphere of the Earth, are by it turned inward, so as to fall on the Moon, and render her distinctly to be seen.

In a lunar eclipse, all to whom the Moon is visible, see her in the same instant of absolute time.

(Solar) eclipses are much more frequent than lunar; but most of the former are invisible at any particular part of the Earth.

The dark shadow of the Moon sometimes reaches to the Earth, eclipsing a small portion of its surface; sometimes that dark shadow is terminated before it arrives at the Earth. In the latter case, the Sun, at the centre of an eclipse, appears like a luminous ring. The eclipse is then called *annular*. (Plate v. Fig. 5.) This beautiful phenomenon was seen in some parts of New England on the morning of April 3, 1791; at Washington, September 17, 1811; and in the eastern parts of the United States, February 12th of the year 1831. The dark shadow of the Moon is longest, when she is in perigee and the Earth in aphelion; shortest, when she is in apogee, and the Earth in perihelion. The inhabitants of our republic have had the satisfaction of viewing two annular eclipses, since the commencement of the present century; one, September 17, 1811, the other, February 12, 1831. According to computation, they will have the pleasure of seeing another, September 18, 1838; the annular eclipses being three for the century.

Two total solar eclipses are computed for the United States during the century; one, June 16, 1806, the other, August 7, 1869. It will appear from this, and from inspection of the tables of the semi-diameters of the Sun and Moon, that annular eclipses of the Sun are more frequent than total eclipses of the same luminary.

The Moon's partial shadow is called her *penumbra*. All the inhabitants over whom this shadow extends, see the Sun partially eclipsed. In Plate vi. Fig. 10.

a b c d represent the Moon's penumbra ; the arch *b d*, its extent on the Earth. The darkness of the penumbra decreases, as it diverges from the dark shadow of the Moon. The motion of the dark shadow and penumbra over the Earth is nearly from west to east ; except at the polar regions, when they sometimes pass in an opposite direction.

The whole number of eclipses in any one year is never less than two, nor more than seven : when two, both are of the Sun ; when seven, four are of the Sun, three of the Moon.*

The line of the Moon's nodes has a constant motion from east to west, or backwards in the ecliptic ; making a complete revolution in 18 y. 223 d. 20 h. 13 m. 32 s. In a year of 365 days, its motion is $19^{\circ} 19' 43''$, completing a revolution in 18 y. 224 d. 4 h. 53 m. when leap year is four times taken ; in 18 y. 223 d. 4 h. 53 m. when leap year is five times included. By the retrograde motion of the nodes, either of them is brought round to the Sun, or passes from the Sun to the Sun again, in 346 d. 14 h. 52 m. 14 s. on a mean. Half of this time only intervenes between one node and the other passing the Sun. When eclipses happen at the ascending node, other eclipses may be expected at the descending node in about 173 d. ; and, after a lapse of the same time, at the ascending node, thus continuing in rotation.

When the Sun and Moon have been in conjunction with the Moon's ascending or descending node, they will be in conjunction again within $28' 12''$ of the same node, after 223 mean lunations. } Thus is formed a regular period of eclipses. | It is completed in 18 y. 11 d. 7 h. 43 m. 19 s. when leap year is four times included ; 18 y. 10 d. 7 h. 43 m. 19 s. when leap year is

* In some books it is stated, that, when there are seven eclipses in a year, five are of the Sun. Such an event seems barely possible. Should it ever happen, two of them must be very slight, the penumbra just touching the pole.

five times included. There is a regular series of returns to each eclipse. Eclipses at the ascending node first strike the Earth at the north, and pass off at the south pole, moving a little southward at each return. Eclipses at the descending node commence at the south, and retire at the north pole. After an eclipse has completed a series, and left the Earth, it will not again return and commence a new series at the same node, till after an absence of more than 12,000 years. The eclipses commencing at one pole are equal in number to those commencing at the other. The irregular motion of the Earth and Moon may accelerate or retard the commencement of a series about one hundred years. In one series an eclipse may visit the Earth but seventy times; it will not surpass seventy-seven times. When an eclipse returns but seventy times, it will occupy about 1,262 years; when it returns seventy-seven times, it will require 1,388 years. The memorable eclipse of June 16, 1806, was total to a large part of New England. It happened at the Moon's descending node. Having traversed the mighty void from the creation, it first met the south pole on the morning of the 6th of March, O. S. 1049, at 10 h. 11 m. 39 s. Each visit has shown it a little farther north. The last return was June 24, 1824. It happened in the evening, the Sun going down a little eclipsed at Washington. It will again visit the Earth, July 8th, 1842. But, being at 2 h. 2 m. 2 s. in the morning, at Washington, it will be invisible in the United States; but will be large and total over a wide extent of the eastern continent. This eclipse will leave the Earth at the north pole on the 11th of May, in the year 2347, N. S. of the Christian era.

The dark shadow of the Moon, when longest, and falling directly on the Earth, extends about 107 miles. In most cases, however, it falls obliquely; in some, very obliquely, when it may cover an extent of more than 900 miles.

The tables make the extent of the penumbra, when least, about 4,500 miles; when greatest, a little more than 7,000 miles. It is very different at different times, varying on account of the distance of the Sun and Moon, but more from the oblique manner in which it often strikes the Earth.

According to the tables in the author's larger work, total darkness in a solar eclipse will never continue in one place more than 5 m. 32 s. The duration will be a little longer, according to the tables of Enfield. Several authors state this duration short of the truth, making it three minutes, or about three minutes. In the June eclipse of 1806, total darkness was considerably short of the greatest possible duration; yet in the southern part of New Hampshire, the author, by the most careful observation, made it 4 m. 20 s. At Sterling, Massachusetts, Robert B. Thomas, the author of the Farmer's Almanac, probably nearer the centre of the shadow as it passed, found the time of total darkness 4 m. 45 s.

The beginning of a general eclipse is when the penumbra first touches the Earth; the ending, when it leaves the Earth. In the same manner, the commencement and end of an eclipse at any particular place, is marked by the approach, or first touching and departure of the penumbra. When the Moon changes in one of her nodes, the penumbra and dark shadow pass over the centre of the Earth, making the longest general eclipse. The duration varies a little with the distance of the Sun; more with the distance of the Moon from the Earth. When the Moon is in apogee, and the Earth in perihelion, it is longest, being then about 6 h. 13 m. The mean duration of a general eclipse is 5 h. 46 m.)
































The position of the Earth's axis, as seen from the Moon or the Sun, greatly affects solar eclipses. The eclipse of 1806 will make a return in 1860, visible in the United States. But the position of the Earth's

axis being different, it will be to us far less than it was in its former visit. *See this eclipse of 1860, as projected by the author in his larger astronomical work.*

What is an eclipse? What heavenly body shines by its own light? What is the form of a planet's dark shadow? Are the shadows of the planets coextensive with the Sun's light? Do the primary planets ever eclipse each other? What do eclipses? What is the greatest length of the Earth's shadow? What is its mean length? Why have we not eclipses at every change and full? Where must the Moon be in order that there may be an eclipse? What is the limit of solar, and what of lunar eclipses? When are lunar eclipses partial? When are they total? and when central? What causes the Moon to be visible when she is eclipsed? Which are the most frequent, solar or lunar eclipses? Why is a solar eclipse sometimes total and sometimes annular? According to calculation, how many annular, and how many total eclipses will be visible in the United States in the present century? At what times will they happen? What is the Moon's penumbra? What is the greatest number of eclipses in a year? What is the least? When two, are they lunar or solar? How are they when seven? In what direction does the line of the Moon's nodes move? In what time does it complete a revolution? When eclipses happen at one node, how long before they may be expected at the other? When the Sun and Moon have been in conjunction at one of the Moon's nodes, how long before they will be in conjunction again near the same node? Is there a regular period of eclipses? How long is it? Where do eclipses at the ascending node first strike the Earth? Where do they pass off? Where do eclipses at the descending node commence and retire? After an eclipse has completed a series, and left the Earth, how long before it will commence a new series at the same node? How many times may an eclipse visit the Earth in one series? In what number of years is a series completed? At what node was the memorable eclipse of June 16, 1806? When did this eclipse first meet the south pole? When was its last return? Why did it not attract notice? When will be its next return? Where will it be visible and total? When, and at what pole, will this eclipse leave the Earth? How many miles does the dark shadow of the Moon extend on the Earth? What is the extent of the penumbra? Why is the extent different at different times? How long will total darkness continue in a solar eclipse? What was the duration of total darkness in the June eclipse of 1806? When does a general eclipse begin and end? When does an eclipse begin and end at a particular place? What varies a little the duration? What is the longest continuance of a general eclipse? What is its mean duration? Has the position of the Earth's axis any effect on solar eclipses?

A Catalogue of Eclipses visible at Washington, and generally throughout the United States, extracted from the Author's larger Work. Commencing with the Year 1831, it is continued through the 19th Century.

The time set to solar eclipses is the middle of each eclipse, as seen at Washington; to lunar, the minute of opposition. Both are reduced to apparent time.

Year.		Month.	D.	H.	M.	A. P. M.	Remarks.
1831		Feb.	12	0	35	P. M.	Annular over a large S. E. section of the Union.
		Aug.	23	4	57	A. M.	
1832		Feb.	1	5	10	P. M.	Visible in the western parts of [the Union.
		July	27	7	34	A. M.	
1833		Jan.	6	2	48	A. M.	Nearly total.
		July	1	7	32	P. M.	
		Dec.	26	4	30	P. M.	
1834		June	21	3	13	A. M.	Total.
		Nov.	30	2	38	P. M.	
		Dec.	15	11	50	P. M.	
1835							
1836		May	1	3	6	A. M.	Visible in Missouri Territory.
		May	15	8	14	A. M.	
		Oct.	24	8	22	A. M.	
1837		Oct.	13	6	29	P. M.	Total.
1838		April	9	9	0	P. M.	Annular in Virginia.
		Sept.	18	4	32	P. M.	
1839							
1840		Aug.	13	2	9	A. M.	Total.
1841		Feb.	5	8	49	P. M.	
		Aug.	2	4	49	A. M.	Total.
1842		July	22	5	43	A. M.	Visible in Astoria and other [western regions.
1843		Dec.	6	7	7	P. M.	
1844		Nov.	24	6	51	P. M.	Total.
		Dec.	9	4	19	P. M.	Small.
1845		May	6			A. M.	Sun rises a little eclipsed.
		Nov.	13	8	7	P. M.	
1846		April	25	0	6	P. M.	
1847							
1848		Sept.	13	1	23	A. M.	Total.
1849		Mar.	8	7	48	P. M.	
1850							
1851		July	13	2	8	A. M.	
		July	28	8	11	A. M.	

Year.	Month.	D.	H.	M.	A. P. M.	Remarks.
1852	Jan.	7	1	3	A. M.	Total.
	Dec.	26			A. M.	Begins 6 h. 28 m.
1853	Jan.	21	1	3	A. M.	Small.
1854	Nov.	4	4	22	P. M.	Very small. Visible in N. E.
1855	May	1	11	6	P. M.	Total.
	Oct.	25	2	42	A. M.	Total.
1856	April	20	4	10	A. M.	
	Oct.	13	6	12	P. M.	
1857						
1858	Feb.	27	4	55	P. M.	Moon rises partially eclipsed.
	Mar.	15	6	16	A. M.	
1859	Feb.	17	5	36	A. M.	Total.
	July	29	5	44	P. M.	Small.
1860	Feb.	6	9	17	P. M.	
	July	18	7	55	A. M.	
1861	Dec.	17	3	9	A. M.	
	Dec.	31	7	45	A. M.	
1862	June	12	1	18	A. M.	Total.
	Dec.	6	2	43	A. M.	Total.
1863	June	1	6	30	P. M.	Total. Moon rises eclipsed.
	Nov.	25	4	21	A. M.	
1864						
1865	April	10	11	29	P. M.	Very small.
	Oct.	4	5	50	P. M.	Very small.
	Oct.	19	10	27	A. M.	
1866	Mar.	30	11	30	P. M.	Total.
1867	Mar.	20	3	45	A. M.	
	Sept.	13	7	30	P. M.	
1868						
1869	Jan.	27	8	21	P. M.	
	Aug.	7	6	5	P. M.	Total over a southern section [of the Union.
1870						
1871	Jan.	6	4	9	P. M.	Moon rises partially eclipsed.
1872	Nov.	15	0	29	A. M.	Very small.
1873	May	12	6	23	A. M.	Commences 4 h. 34 m. Total in
1874	Oct.	25	2	37	A. M.	Nearly total. [the W. States.
1875	Sept.	29	6	12	A. M.	
1876	Mar.	10	1	5	A. M.	
	Mar.	25	4	45	P. M.	Small.
1877	Aug.	23	6	2	P. M.	Total. Moon rises eclipsed.
1878	Feb.	17	5	58	A. M.	
	July	29	5	35	P. M.	
	Aug.	12	7	3	P. M.	
1879						

Year.	Species	Month.	D.	H.	M.	A. P. M.	Remarks.
1880	☉	Dec.	31	7	42	A. M.	
1881	☾	June	12	1	56	A. M.	Total.
1882							
1883	☾	Oct.	16	2	8	A. M.	[the Union.
1884	☾	April	10	6	47	A. M.	Total in the western parts of
	☾	Oct.	4	5	14	P. M.	Visible, and total after the Sun
1885	☉	Mar.	16	1	28	P. M.	[sets.
	☾	Sept.	24	2	56	A. M.	[ible in the Western States.
1886	☉	Mar.	5			P. M.	Commences about sunset. Vis-
	☉	Aug.	29	6	23	A. M.	Very small.
1887	☾	Feb.	8	5	4	A. M.	
1888	☾	Jan.	28	6	6	P. M.	Total.
	☾	July	23	0	35	A. M.	Total.
1889	☉	Jan.	1			P. M.	Penumbra touches Washing-
	☾	Jan.	17	0	18	A. M.	[ton about sunset.
1890							
1891	☾	Nov.	15	7	36	P. M.	
1892	☾	May	11	6	0	P. M.	Visible after sunset.
	☉	Oct.	20	1	40	P. M.	
1893							
1894	☾	Sept.	14	11	24	P. M.	
1895	☾	Mar.	10	10	28	P. M.	Total.
	☾	Sept.	4	0	49	A. M.	Total.
1896	☾	Aug.	23	1	55	A. M.	
1897	☉	July	29	9	45	A. M.	
1898	☾	Jan.	7	7	16	P. M.	Small.
	☾	Dec.	27	6	37	P. M.	Total.
1899	☾	Dec.	16	8	34	P. M.	
1900	☉	May	28	8	40	A. M.	

CHAPTER IX.

Divisions of Time.

TIME, as measured by the celestial luminaries, is divided into periods, cycles, years, months, weeks, days, hours, minutes, seconds, and sometimes farther sexagesimal parts.

Periods, in astronomical reckoning, are large divisions of time. The *Chaldean Period* is a circle of (25,858 years.) This period respects the motion of the terrestrial poles. At the termination of it, the axis of the Earth points to the same stars as at the beginning.)

The *Julian Period* is formed by multiplying together the cycles 28, 19, and 15. It consists of 7,980 years.) The creation of the world, according to the common computation, was on the 706th year, and the Dionysian era of Christ's birth, on the 4,713th year, of this period. According to some, the birth of Christ was earlier by four years. The Julian period is found of use in comparing the dates of ancient events.

The *Dionysian Period*, or circle of Easter, consists of 532 years, formed by multiplying the cycle of the Sun, 28, by that of the Moon, 19.

CYCLES ARE REVOLUTIONS OF TIME.

The *Cycle of the Sun* consists of 28 years.) By this cycle the days of the week are brought to the same days of the month, the Sun to the same signs and degrees of the ecliptic, with little variation; and the leap years to the same state as at the commencement of the cycle. Each of these returns, separately, in a much shorter period. But, by the cycle, they are brought to coincide.

The *Cycle of the Moon* is the *Golden Number*. It

is a period of 19 years, at the expiration of which, the changes and fulls, with the other aspects of the Moon, return to the same months, and days of the month, as at the beginning, or within a day of the same time.

The *Roman Indiction* is a period of 15 years, established by Constantine, in the year 312, for indicating the times of certain payments, made by the subjects to the government.

For finding the cycle of the Sun, golden number, and indiction, add 4,713 to the year of the Christian era, and divide the sum by 28, 19, and 15, respectively; the remainders are the numbers sought for the year.

Required the cycle of the Sun, golden number, and indiction, for the year 1831.

4713	28)6544(233	19)6544(344	15)6544(436
1831	56	57	60
6544	94	84	54
	84	76	45
	104	84	94
	84	76	90
	20 Cycle of Sun.	8 Golden number.	4 Indiction.

The *Epact* is the excess of the solar above the lunar year of 354 days, or 12 mean lunations. It is taken for the age of the Moon, on the first day of January.

For finding the Julian epact, multiply the golden number of the year by 11; the product, if less than 30, is the Epact. But, if the product exceed 30, divide it by 30; the remainder is the epact.

To find the Gregorian epact, the Julian epact must be first found. From this subtract 12, the number of days between the old and new style in the present century; the remainder is the epact required.* If

* The rule of Mr. Pike and some others, to deduct 11 for the difference between the Julian and Gregorian epact, applies to the last

nothing remain, 29 is the epact. If the subtraction cannot be made, add 30 to the Julian epact, and subtract as before.

The golden number and epact are little used at the present time; especially where accuracy is required. The Roman indiction, still less important, is retained in our almanacs; why, is difficult to be conceived, unless as it is used in forming the Julian period.

A Year.

(A complete revolution of the seasons) constitutes a year. The difference in the years, the tropical, the sidereal, and anomalistic, has been considered. The civil solar year consists of (365 days) and in bissextile, of 366. In this manner it is used in the United States, and most European nations. The lunar year consists of (12 lunar months, or mean lunations) computed at 354 days, the surplus arising from the minutes and seconds of the lunation being generally dropped in the computation. In this calendar a (month is added every third year) to make the lunar coincide with the solar year. This month is intercalary, or *embolimic*.

The Jews computed their time by (lunar years). "But, by intercalating no more than a month of thirty days, which they called *Ve-Adar* (every third year, they fell 3 $\frac{1}{2}$ days short of the solar year in that time."

The year of the Greeks consisted of (12 months, of 29 and 30 days, alternately taken, comprising 354 days, or about 12 mean lunations.) This lunar year was with difficulty connected with the solar year, or the revolution of the seasons, so as to make a particular month fall at the same season in successive years.

century only. The difference between the styles ought, in all computations of the kind, to be deducted. Hence the practice of celebrating the birth-day of Washington on the 22d of February, in the present century, must be erroneous. The celebration ought to be on the (23d of February.)

"The Olympic games were celebrated every fourth year, during the full Moon, next after the summer solstice; and the year of the Greeks was so regulated as to make this full Moon the first month.) This purpose was effected by intercalations; but these were managed so injudiciously, that, in the time of Meton, the calendar and the celebration of the festivals had fallen into great confusion."

The ancient Romans computed their time by the (*Lustrum*, a period of four years.) They also reckoned by lunar years, as established by Romulus; till Julius Cæsar reformed the calendar, introducing the system of computation known as the *Julian calendar* to the present time. In this calendar three years were common, consisting of 365 days each.) Every fourth year, the 24th day of February was twice reckoned, making it consist of 366 days. This, being the 6th of the calends of March, was called *bis sextus dies*, denominated by us *bissextile*. The intercalary day is now added to the last of February, and from it the year is called *bissextile*, or *leap year*. The Julian calendar long prevailed in Europe. But, from observations on the time of Easter, the civil year was found to be too long for the tropical, and another attempt was made to reform the calendar.

The vernal equinox fell on the 21st of March) at the time of the Council of Nice, 325 of the Christian era. In 1582, Pope Gregory XIII. observed, that the same equinox happened ten days earlier in the year than it had done at the time of the Nicene Council.) To correct the style, he altered the calendar ten days, ordering, that the 5th day of October should be called the 15th.) Thus amended, the style was called the *Gregorian*, or *new style*. Though adopted in several European countries, it was not received into England till the year 1752.) The Julian calendar, or old style, still prevails in Russia.) In the present century, the difference between the old style and the new is twelve days, as before stated.

Pope Gregory stopped not at the alteration of the style. He endeavored to establish a principle, by which the civil year and the tropical would in future coincide. By this principle, bissextile is to be omitted three times in 400 years. When the centuries of the Christian era are divided by four, if there be a remainder, the year at the end of the century is to be reckoned common; but if nothing remain, the leap year is to be retained, or the last year of the century is to be reckoned bissextile. Though the year 1800 would have been a leap year in the Julian calendar, yet it was considered common in all our almanacs on the Gregorian principle. Our computations, to the present time, are made on the same principle. Thus, at the end of the 19th century, the leap year is to be omitted, there being a remainder, when 19 is divided by 4; but the year 2000 will be considered bissextile; because there is no remainder when 20 is divided by 4.

The omission of three bissextiles in 400 years does not bring the civil year exactly to coincide with the tropical, as computed by La Place. The former still exceeds the latter 20 seconds, 24 thirds. This excess will amount to a day in about 4236 years. The omission of one bissextile in 129 years, would bring the different computations to great nearness.

Months are the principal divisions of a year. These are lunar, solar, and civil. The sidereal lunar month is the time the Moon is passing from a point in the heavens to the same again; as from a star to the same star, as before stated. But the principal lunar month is a lunation; or the time the Moon is passing from one change to another. This seems to have given the name to this division of time; or to be the foundation of *months*. The solar month is the time the Sun is passing one of the signs of the ecliptic, or the 12th part of a year.

Civil months are of two kinds. The weekly month,

always equally long, consists of four weeks. This is the true legal month. "A month, in law," says Blackstone, "is a lunar month, or twenty-eight days, unless otherwise expressed; not only because it is one uniform period, but because it falls naturally into a quarterly division by weeks. Therefore a lease for *twelve months* is only for forty-eight weeks; but, if it be for a *twelvemonth*, in the singular number, it is good for the whole year."

/ The other months are those in our calendar. / They are / Roman in their origin. / The Latin names are retained, some of them assuming an English termination. The sixth month was called *Sextilis*, till the time of Augustus Cæsar. It was changed to *Augustus*, in honor of that emperor. / To heighten the compliment, (a day was taken from the last of February, and added to August. Before that time, February, in a common year, consisted of 29 days, August of 30.*

A *week*, a well-known portion of time, and old as creation, undoubtedly had its origin in the resting of Jehovah from his work, and the establishment of the Sabbath. It consists of seven days.

Days are *artificial* or *natural*. / The *artificial day* is continually varying in length in most latitudes, being the time the Sun is above the horizon. / The *natural day* is the time in which any meridian of the Earth moves from the Sun round to the Sun again, being 24 hours. \ This is subject to a fractional variation at different seasons. The ancient Egyptians began their day (at midnight). \ (This is the practice of the United States, and of most European nations.) It is the civil day with us, and is divided into two twelves. From

* The number of days in each month may be remembered by the following lines:

Thirty days hath September,
April, June, and November;
All the rest have thirty-one,
Saving February alone.

common practice, it is too well known to need explanation. The Jews began their days (at the setting of the Sun.) They divided the night and the day each (into 12 equal parts.) As this was done at all seasons of the year, not only the days, but the hours, or divisional parts, must have been of unequal length; though not so unequal as such a division would be with us, Palestine being nearer the equator than most of the United States. The ancient Greeks also began their day at Sun-setting. The same practice is followed among the moderns, by the (Bohemians, the Silesians, the Italians, and Chinese.) The day was commenced at Sun-rising by the (Babylonians, Persians and Syrians.) This is the manner of computation by the modern (Greeks.)

The nautical, or sea day, commences (at noon,) 12 hours before the civil day. (The first 12 hours are marked P. M., the last, A. M.) The astronomical day begins (at noon,) 12 hours after the civil day, and is reckoned, numerically, (from 1 to 24.)

An hour is the (24th part of a natural day.) This division of time is very ancient. "Herodotus observes, that the Greeks learned from the (Egyptians) among other things, the method of dividing the day into 12 parts. The division of the day into 24 hours was not known to the (Romans) before the Punic war. Till that time, they only regulated their days by the rising and setting of the Sun." The day was divided by them into four watches, commencing at 6, 9, 12, and 3 of the clock. The night was divided, in the same manner, into four watches, each consisting of (three hours.)

The remaining divisions of time all proceed in the well-known sexagesimal order: the hour is divided into 60 minutes; the minute into 60 seconds; the second into 60 thirds; and so on to fourths and fifths.

The *dominical letter* is deserving a place in a work of this kind. The first seven letters of the alphabet were formerly placed in almanacs (for the days of the

week. Introduced by the primitive Christians, they were used instead of the nundinal letters of the Roman calendar. One of these, standing for the Sabbath, was written in capitals, and called the *dominical* letter, from *Dominus*, the Latin word for *Lord*. The dominical letter is still retained in our almanacs, while figures are substituted for the other letters.

If 365, the days in a common Julian year, be divided by 7, the number of days in a week, 1 will remain. If there were no remainder, and no bissextile, each succeeding year would begin on the same day of the week. But, one remaining, when a common year is thus divided, each year will begin and end on the same day of the week. When January begins on Sunday, *A* is the dominical letter for that year. But the next year must commence on Monday; *A*, therefore, or the substituted figure, is set at that day. The Lord's day being the seventh of the month, *G* will be the dominical letter for that year. As the following year must commence on Tuesday, *F* is the dominical letter for that year. Thus the letters would follow, *G, F, E, D, C, B, A*, in retrograde order. At the end of seven years, the days of the week would return to the same days of the month as at the beginning. But, bissextile having 366 days, if this be divided by 7, there will be a remainder of 2. Thus there must be an interruption of the regular returns.

The letters were placed in such order, that *A* stood at the first day of January, *B* at the second, *C* at the third; thus on throughout the seven. The same were repeated in succession through the year. In each succeeding year, therefore, the same letters stood at the same days of the month. This always brought *C* to the 28th of February. That this order might not be interrupted by leap year, *C* was placed at the 29th also; or, according to some tables, *D* was repeated. Thus the same letters were set to the days of the succeeding months in bissextile, as in common years. Let

a year commence with *D*, as the dominical letter; *C*, at the 28th of February, must in that case stand for Saturday; *C* also must be against the 29th, and, of course, being for the Lord's day, must be dominical; or, if *D* be repeated, *C*, at the 7th of March, becomes dominical, and thus continues through the year. The next year would commence two days later in the week. On account of this *leaping* in the retrograde order of the letters, the seven occupy five years in a revolution, when leap year is twice included; six, when it is once included. Hence the days of the week return to the same days of the month in (five or six years,) according as bissextile is twice or but once included. In 28 years, the seven letters will always have five revolutions, except at the end of the centuries, when leap year is omitted.

The table following shows the dominical letter for 6000 years of the Christian era, according to the new style, or Gregorian calendar: †

A Table of Dominical Letters for 6000 Years of the Christian Era, N. S.

			1 0 0	2 0 0	3 0 0	4 0 0
			5 0 0	6 0 0	7 0 0	8 0 0
			9 0 0	1 0 0	1 0 0	1 2 0 0
			1 3 0 0	1 4 0 0	1 5 0 0	1 6 0 0
			1 7 0 0	1 8 0 0	1 9 0 0	2 0 0 0
			2 1 0 0	2 2 0 0	2 3 0 0	2 4 0 0
			2 5 0 0	2 6 0 0	2 7 0 0	2 8 0 0
			2 9 0 0	3 0 0 0	3 1 0 0	3 2 0 0
			3 3 0 0	3 4 0 0	3 5 0 0	3 6 0 0
			3 7 0 0	3 8 0 0	3 9 0 0	4 0 0 0
			4 1 0 0	4 2 0 0	4 3 0 0	4 4 0 0
			4 5 0 0	4 6 0 0	4 7 0 0	4 8 0 0
			4 9 0 0	5 0 0 0	5 1 0 0	5 2 0 0
			5 3 0 0	5 4 0 0	5 5 0 0	5 6 0 0
			5 7 0 0	5 8 0 0	5 9 0 0	6 0 0 0
Years less 100.			C	E	G	B A
1	29	57 85	B	D	F	G
2	30	58 86	A	C	E	F
3	31	59 87	G	B	D	E
4	32	60 88	F E	A G	C B	D C
5	33	61 89	D	F	A	B
6	34	62 90	C	E	G	A
7	35	63 91	B	D	F	G
8	36	64 92	A G	C B	E D	F E
9	37	65 93	F	A	C	D
10	38	66 94	E	G	B	C
11	39	67 95	D	F	A	B
12	40	68 96	C B	E D	G F	A G
13	41	69 97	A	C	E	F
14	42	70 98	G	B	D	E
15	43	71 99	F	A	C	D
16	44	72	E D	G F	B A	C B
17	45	73	C	E	G	A
18	46	74	B	D	F	G
19	47	75	A	C	E	F
20	48	76	G F	B A	D C	E D
21	49	77	E	G	B	C
22	50	78	D	F	A	B
23	51	79	C	E	G	A
24	52	80	B A	D C	F E	G F
25	53	81	G	B	D	E
26	54	82	F	A	C	D
27	55	83	E	G	B	C
28	56	84	D C	F E	A G	B A

The dominical letter for any year of the first century is found in the column of letters under 100, opposite to the year. For a year in any century after the first, find the century preceding the year at the top: under this, and opposite to the year of the century, in the column for years less than 100, is the dominical letter sought.

EXAMPLE.

Under 1800, opposite to 31 in the left hand column, is B, the dominical letter for 1831.

The dominical letter being known, it is easy to find the day of the week on which any month begins, by the following table.

A	B	C	D	E	F	G
Jan.	May	Aug.	Feb.	June	Sept.	April
Oct.			March		Dec.	July
			Nov.			

The following couplet is designed to assist the memory.

All days decline ; great blessings end ;
Good Christians find a during friend.

The first letters of these twelve words are the same as those at the beginning of each month.

If the letter set at the first day of a month be before or after the dominical letter in any year, the day on which the month begins is before or after the Lord's day, and is as far distant as the commencing letter is distant from the dominical letter. Thus, if *A* be the dominical letter, January begins on the Sabbath ; February and March on Wednesday. If *B* be the dominical letter, January begins on Saturday, February and March on Tuesday.

A Table showing at what Days of the Months the Letters formerly stood, and where the Dominical Letters now stand.

D. Letters.	A	B	C	D	E	F	G
	1	2	3	4	5	6	7
January 31	8	9	10	11	12	13	14
October 31	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31	1	2	3	4
Feb. 28-29.	5	6	7	8	9	10	11
March 31.	12	13	14	15	16	17	18
Nov. 30.	19	20	21	22	23	24	25
	26	27	28	29	30	31	1
	2	3	4	5	6	7	8
April 30.	9	10	11	12	13	14	15
July 31.	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30	31	1	2	3	4	5
	6	7	8	9	10	11	12
Aug. 31.	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31	1	2
	3	4	5	6	7	8	9
Sept. 30.	10	11	12	13	14	15	16
Dec. 31.	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
	31	1	2	3	4	5	6
	7	8	9	10	11	12	13
May 31.	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31	1	2	3
	4	5	6	7	8	9	10
June 30.	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	

What are periods? How long is the Chaldean period? What takes place at the termination of this period? How is the Julian period formed? How long is it? What is its use? Of how many years does the cycle of the Sun consist? What is effected by this cycle? How long is the cycle of the Moon, or golden number? What takes place at the expiration of this cycle? What is the Roman indiction? How are the cycle of the Sun, golden number and indiction found? What is the epact? How is the Julian epact found? How is the Gregorian? Are the golden number, epact, and indiction of much use? What is the difference between old and new style in the present century? Which is the proper day for the celebration of Washington's birth? What constitutes a year? Of what does the civil solar year consist? How long is a lunar year? What was added to make this year coincide with the solar year? How did the Jews compute their time? What defect was there in their computation? Of what did the year of the Greeks consist? Was their year easily connected with the solar year? When were the Olympic games celebrated? At what season was the first month of the Grecian year? How did the ancient Romans compute time? They reckoned by lunar years, established by whom? Who established the Julian calendar? In this calendar how many years were common? When was the day added in leap year? Why was it called *bissextile*? On what day of March did the vernal equinox happen at the time of the Council of Nice, in the year 325? In 1582, what did Pope Gregory XIII. observe? To correct the style, what did he do? When was the Gregorian, or new style, adopted in England? Where does the Julian, or old style, still prevail? What principle did Pope Gregory endeavor to establish? By his principle, how many bissextiles are to be omitted in four hundred years? How can it be ascertained what bissextiles are to be omitted? Has any bissextile been of late omitted? Does the civil year, as now established, exactly coincide with the tropical? What omission would bring the two computations to great exactness? What is a sidereal lunar month? What is the principal lunar month? Of how many kinds are civil months? Of what does the weekly month consist? What is the true legal month? What are the other months? Of what origin are they? How are the names? What was the sixth month formerly called? Why was it called *August*? How was the compliment heightened? What seems to have been the foundation of weeks? What is an artificial day? What is a natural day? When did the ancient Egyptians begin their day? What nations now begin their day at midnight? When did the Jews begin their day? How did they divide the night and the day? What modern nations begin their day at sunset? What ancient nations commenced their day at sunrise? What moderns? When does the nautical, or sea-day, commence? How are the hours marked? When does the astronomical day begin? How is it reckoned? What is an hour? From whom did the Greeks learn their method of dividing the day? Who divided the day and the night each into four watches? How long was a watch? After hours, in what

order do all the remaining divisions of time proceed? How were the first seven letters of the alphabet formerly placed in almanacs? Who introduced them? Why was one of these called *dominical*? If a common year begins on Monday, on what day will the next year begin? What prevents the dominical letters from proceeding in a retrograde order, and returning again at the end of seven years? In what order were the letters placed in almanacs? What causes two dominical letters in leap year? In how long time do the days of the week return to the same days of the month? What is a convenient couplet? Why is it convenient? If you know the letter at the beginning of a month, and the dominical letter, how will you find on what day of the week the month begins?

CHAPTER X.

Obliquity.

THE obliquity of the equator to the plane of the ecliptic, being the cause of the variety of seasons, the different length of days and nights, and the pleasing vicissitudes resulting from the varying year, is well deserving a place, even in a compendium of astronomy. The principal inquiry is, whether the obliquity remains the same, or is subject to a constant diminution.

"The obliquity of the ecliptic to the equator," says Dr. Brewster, "was long considered a constant quantity. Even so late as the end of the 17th century, the difference between the obliquity, as determined by ancient and modern astronomers, was generally attributed to inaccuracy of observation, and a want of knowledge of the parallaxes and refraction of the heavenly bodies. It appears, however, from the most accurate modern observations, at great intervals, that the obliquity of the ecliptic is diminishing. By comparing about 160 observations of the ecliptic, made by ancient and modern ob-

servers, with the obliquity of $23^{\circ} 28' 16''$, as observed by Tobias Mayer, in 1756, we have found that the diminution of the obliquity of the ecliptic, during a century, is $51''$; a result which accords wonderfully with the best observations." This would bring the obliquity at the present time, 1831, to $23^{\circ} 27' 38''$.

The above statement, though contrary to the opinion of some philosophers, is in accordance with the true principles of Newtonian philosophy, and is corroborated by the best modern astronomers. Professor Vince, having stated the observations of many authors, ancient and modern, concludes: "It is manifest, from these observations, that the obliquity of the ecliptic continually decreases; and the irregularity, which here appears in the diminution, we may ascribe to the inaccuracy of the observations; as we know that they are subject to greater errors than the irregularity of this variation."

The following table will give an idea of the diminution of the obliquity for many centuries. It was extracted from Rees's Cyclopædia.

Obliquity of the Ecliptic, from Observations at different Times.					Mean Obliquity for 40 Centuries.				
	B. C.	°	'	"	B. C.	°	'	"	
Pytheas,	324	23	49	23	900	23	50	26	
Eratosthenes,	230	23	51	20	400	23	46	30	
Hipparchus,	140	23	51	20	0	23	43	15	
	A. D.				A. D.				
Ptolemy,	140	23	48	45	100	23	42	26	
Arzachel,	1104	23	33	30	500	23	39	6	
Propatius,	1300	23	32		1000	23	34	51	
Waltherus,	1476	23	30		1500	23	30	33	
Tycho Brahe,	1584	23	31	30	1700	23	28	49	
Kepler,	1627	23	30	30	1800	23	27	57	
Flamsteed,	1690	23	29		2000	23	26	13	
Mayer,	1756	23	28	16	2500	23	21	52	
Maskelyne,	1800	23	27	56.6	3000	23	17	31	

A small difference will be seen between the statement of Dr. Rees and that of Professor Vince, respecting the obliquity, as observed by some of these authors. But as the general principle is not affected, it may be useless to attempt a reconciliation.

The part of the table on the left was taken from observation. It will be found very nearly to coincide with that on the right, formed by calculation from the observations of the most accurate modern astronomers.

The attraction of the Moon on the spheroidal figure of the Earth is, without doubt, the cause of the diminution above stated. [*See a demonstration of this in the author's larger work on astronomy.*] The action of the Sun upon the same figure must have an effect similar to that of the Moon; but far less in quantity, on account of his immense distance. The principle is nearly similar to that of the tides, as may be seen in the demonstration.

If such be the cause of diminution, the obliquity must continually decrease, and in time become extinct. But, at the present ratio of diminution, such an event cannot occur under about 160,000 years, a period stretching beyond the most distant wish of the present inhabitants respecting the concerns of this world.

The variety of seasons, it is true, must cease at such an event. But long ere that time the earth may be "*dissolved*;" or it may be renovated, so as to produce "*seed time and harvest, and summer and winter.*"

Why does the obliquity of the equator to the plane of the ecliptic deserve a place in a compendium of astronomy? How was this obliquity long considered? To what was the difference between the obliquity, as determined by ancient and modern astronomers, long attributed? Does it appear now, that the obliquity is increasing or diminishing? What is the diminution in a century? What is the cause of the diminution? If the Moon's attraction on the spheroidal figure of the Earth be the cause of diminution in the obliquity, what must in time be the effect? According to the present diminution of the obliquity, how many years would be required to bring the equator to the ecliptic? Ought the present inhabitants to be anxious respecting such an event?

CHAPTER XI.

Parallax.

THE *true* place of a heavenly body is the situation in which it would appear, if seen from the centre of the earth; the *apparent*, where it is seen from the surface. The angular difference between these, the true and apparent place, is what is understood by *parallax*. It is equal to the angle under which the semi-diameter of the earth would appear at the Sun or a planet. Parallax is greatest at the horizon, called *horizontal parallax*. Decreasing from this, it becomes nothing at the zenith. Plate v. Fig. 7: let A B D be the Earth; C its centre; M N O P the place of the Moon at different altitudes. When the Moon is at M, she would appear from the Earth's centre among the stars at E; but as seen from the surface at A, she appears at F. When at N, she would be seen from the centre at G; but from A she seems at H. At O, her parallax being lessened, she would be seen from the different stations at I and at K. Having no parallax at P, she appears at the same place from C and from A, being seen in the zenith as at Z.

This is called *diurnal* parallax. *Annual* parallax is the difference between the apparent place of a heavenly body, as seen from opposite points of the Earth's orbit. The diameter of this orbit is about 190 millions of miles. A spectator at one season of the year, as the 20th of June, must be the whole of this diameter distant from his place at the opposite season, the 20th of December. Hence an object, unless inconceivably distant, as seen from one part, must appear in a very different place, from the same object, as seen from the opposite part.

Diurnal parallax, usually denominated *parallax*, with-

out epithet, increases with the nearness of the body to the Earth. The Moon, being the nearest heavenly body, has the largest parallax; while the fixed stars, being immensely distant, have no perceptible parallax, the semi-diameter of the Earth appearing, at that distance, no more than a point.

Parallax always depresses a body, making it appear below its true place.

The horizontal parallax of the Moon has long been known. It is of great importance in the calculation and projection of eclipses.

The parallax of the Sun has been an object of attention from the greatest antiquity. Aristarchus, an astronomer of Samos, flourished about the middle of the third century before Christ. He proposed to find this parallax by observing the instant when exactly one half of the Moon's disk is illuminated. This happens a little before the first, and a little after the last, quarter. The Moon, as seen from the Sun, is then at her greatest elongation. In the triangle formed by the Earth, the Sun, and the Moon, the angle at the Moon is a right angle; and the angle formed at the Earth, by the Moon's distance from the Sun, is taken by observation. If, then, the distance of the Moon from the Earth be known, the distance of the Sun may be found by an easy process in rectangular trigonometry. Hipparchus proposed to obtain a triangle for finding the Sun's parallax, by observing the exact time the Moon is in passing the Earth's shadow, in a lunar eclipse. But all attempts to ascertain this parallax prior to the seventeenth century, can scarcely be called approximations to the truth.

The present manner of finding the Sun's parallax by the transit of Venus over the disk of the Sun, is considered the greatest improvement in modern astronomy, as it furnishes a means of ascertaining, with sufficient accuracy, the magnitude of the planets, and their distance from the Sun. The important use to be made of this transit was first suggested by Dr. Halley. Kepler

first predicted the passing of planets over the Sun's disk, foretelling the transit of Mercury in 1631, and the transits of Venus in 1631 and in 1761; but it seems not to have occurred to him, that these transits might be used in finding the distances of the planets. Dr. Halley, early in life, formed an idea, that such transits might be used for finding the parallax of the Sun. The thought occurred to him when he was at the island of St. Helena, viewing the stars round the south pole; and when he had an accurate view of Mercury passing over the Sun's disk. But, Mercury being too near the Sun to be conveniently used for the intended purpose, it is necessary to have recourse to Venus.

The transit of Venus happens but seldom. Horrox, a young English astronomer, and his friend, Mr. Crabtree, appear to have been the first who had a view of this singular and pleasing phenomenon. On the 24th of November, O. S., 1639, they saw Venus passing over the Sun's disk. But their observations were imperfect, the Sun going down in England during the transit. From this time, no other transit of Venus occurred until the 6th of June, 1761. Dr. Halley, in a paper communicated to the Royal Society, in the year 1691, gave particular directions for taking this, and the following transit, in 1769, though he knew they must happen some time after his decease.

For the manner of taking the transit, and constructing the mathematical figures for obtaining the parallax, the student is referred to the author's larger work, Ferguson, and Prior, on the same subject.

The Sun's horizontal parallax is equal to the angle under which the semi-diameter of the Earth would be seen at the Sun, as before stated. This angle being obtained, and the semi-diameter of the Earth known, the distance of the Earth from the Sun may be easily found, by those who are tolerably versed in trigonometry. When this distance is known, the distances of the other planets from the Sun may be easily ascer-

tained ; for the great law of Kepler applies :—As the square of the Earth's periodical time, a sidereal year, is to the cube of its distance ; so is the square of any other planet's periodical time, to the cube of its distance from the Sun. A concise method of determining the distances of the other planets from the Sun by the distance of the Earth, may be to assume a proportional distance for the Earth, and say,—As the proportional distance of the Earth from the Sun is to its real distance ; so is the proportional distance of any other planet from the Sun, to its real distance. The proportional distances of the planets was not difficult to obtain ; and has been long known.

If the distance of the Earth from the Sun be assumed at 100,000, the distances of the other principal planets would be,

Mercury,	38,947 ;
Venus,	71,578 ;
Mars,	151,579 ;
Jupiter,	515,789 ;
Saturn,	947,368 ;
Herschel,	1,894,736.

It is amusing and gratifying to know what vast interest was felt in the transit of 1761, and what vast pains were taken to observe it with accuracy. Persons were sent into various parts of the world, to make observations on this important phenomenon.

Mr. Short, of London, made his observations at the Saville house in London, in the presence of several of the royal family. The transit was observed at the royal observatory at Greenwich, and other places in England ; at Paris, by De la Lande ; at Stockholm observatory, latitude $59^{\circ} 20\frac{1}{2}'$ N., longitude 18° E. from Greenwich, the whole transit being visible, was observed by Wargentin. It was also observed at Hernosand in Sweden ; at Torneo in Lapland ; at Tobolsk in Siberia ; at Madras, at Calcutta, and at the Cape of Good Hope. Dr. Maskelyne's observations at St.

Helena, interrupted by the cloudy state of the weather, were not completely successful. The same happened in part at London, and at the royal observatory in Greenwich. "Early in the morning," June 6th, "when every astronomer was prepared for observing the transit, it unluckily happened, that, both at London and the royal observatory at Greenwich, the sky was so overcast with clouds, as to render it doubtful whether any part of the transit should be seen; and it was 38 minutes 21 seconds past seven o'clock, apparent time, at Greenwich, when the Rev. Mr. Bliss, astronomer royal, first saw Venus on the Sun."

Mr. Short took great pains in computing the Sun's parallax from the best observations, both in England and in other countries, on this transit of 1761, and found it to have been $8.52''$, on the day of the transit, when the Earth was very near its aphelion, or the Sun near its greatest distance from the Earth; consequently $8.65''$, when the Sun is at its mean distance. Prior, in his Lectures, considers this mean parallax $8.73''$, which does not materially differ from the above statement. In the projection of eclipses, the parallax of the Sun is usually considered $9''$.

The observations on the transit of 1769 did not materially differ in their result from those of 1761. They rather confirmed the parallax deduced from the prior observations.

What is parallax? To what is it equal? What is the difference between diurnal and annual parallax? Does diurnal parallax increase or decrease with the nearness of the heavenly body? Does parallax make a body appear above or below its true place? In what is the horizontal parallax of the Moon of great importance? How did Aristarchus propose to find the Sun's horizontal parallax? How did Hipparchus propose to obtain a triangle for finding the Sun's parallax? Who first suggested the use to be made of the transit of Venus over the Sun's disk? What did Kepler predict? How was Dr. Halley engaged when the thought occurred to him that transits might be used for finding the Sun's parallax? Who first viewed Venus passing over the Sun's disk? When was the first transit of Venus observed? Who gave directions for taking the

transits of 1761 and 1769? If the distance of the Earth from the Sun be known, how can the distance of the other planets be ascertained? Was there much interest felt in the transit of 1761? Where was it observed? What prevented the transit from being fully observed in some places? From the various observations on the parallax, what did Mr. Short make the parallax? From this, what would be the mean parallax? What effect had the observations on the transit of 1769 on the result of the preceding observations?

CHAPTER XII.

The Fixed Stars.

THE *fixed stars* are so denominated from their always retaining the same situation in relation to each other. We have seen, that the Earth is, at one season of the year, 190,000,000 miles distant from its situation at the opposite season; yet these stars have no sensible parallax. The star which is north at one time, is north at any other time. Most of the stars, indeed, appear to have a diurnal revolution round the Earth; but this arises from the rotation of the Earth on its axis, and is no more than is caused by that rotation.

That the stars always retain the same apparent situation, must be owing to their immense and inconceivable distance. Let two persons be placed one rod distant from each other, east and west. An object, ten rods distant, which is due north from one, will easily be perceived not to be north of the other. But let the object be ten miles distant from these observers, and if it be north of one, it will scarcely be perceived not to be north of the other; the angle can be ascertained only by nice observation. Let this principle be applied to the fixed stars, and the student will be sensible, that their

distance is truly immense. We form very inadequate ideas of the Earth's distance from the Sun ;* of course of twice that distance. But this immense distance, 190,000,000 miles, makes no perceptible difference in the situation of the fixed stars, even when viewed with the nicest instruments. "From what we know," says Mr. Ferguson, "of the immense distance of the stars, the nearest may be computed at 32,000,000,000,000 of miles from us, which is farther than a cannon ball would fly in 7,000,000 of years."²

From the distance of the stars it may be concluded, that they shine by their own native light ; and not by the reflected rays of the Sun. For those rays, decreasing in number in any given space as the squares of the distances increase, cannot by reflected light make objects visible at a distance so inconceivably great.

The fixed stars are, without doubt, suns to other systems. Thus they are now considered by the unanimous consent of astronomers. They may be distinguished from the planets by the twinkling of their light. The diameter of a star appears much less viewed through a good telescope, than when seen without the aid of instruments.

Not more than 1000 stars are visible to the naked eye in either hemisphere. They seem, indeed, innumerable, when, in a clear evening, we turn our eyes towards the heavens. But, in attentive observation, most of those bright spots, which appeared to be stars, vanish. They are probably reflections from minute particles of various kinds continually floating in our atmosphere. The British catalogue contains not more than about 3,000 stars, in both hemispheres ; though it includes many not visible to the naked eye. By improved reflecting telescopes the number is found to be great beyond all conception. "Dr. Herschel says that, in the most crowded part of the milky way, he has had fields of view, that contained no less than 588 stars, and

* See the time it would require a courier to pass from the Earth to the Sun, Chap. I., Sec. VII.

these were continued for many minutes ; so that, in a quarter of an hour, he has seen 116,000 stars pass through the field of view of a telescope of only 15' aperture ; and at another time, in 41 minutes, he saw 258,000 stars, pass through the field of his telescope."*

Many stars appear single to the naked eye, which, on being viewed with a good telescope, are found to consist of two, three, or more stars. Some are denominated by Dr. Herschel *insulated* stars, because they seem removed from the attractive force of other stars. Such are our Sun, Arcturus, Capella, Sirius, and many others.

"A binary sidereal system, or double star, properly so called, is formed by two stars situated so near each other as to be kept together by their mutual attraction." It is, however, evident that stars may be situated, one nearly behind the other, so as to appear binary, though immensely distant.

The double star *Epsilon*, Boötes, is beautiful, composed of two stars, one light red, the other a fine blue. Plate viii. Fig. 3, represents this star, as seen by telescopes of different magnifying powers.

The double star *Zeta*, in the constellation Hercules, is composed of two stars ; the greater a beautiful bluish white, the less a fine ash color.

The star *Delta*, of the Swan, is binary, composed of two stars very unequal in their apparent magnitude ; the larger white, the less reddish.

The pole-star is binary, composed of two stars of very unequal magnitude ; the larger white, the less red. In Plate viii. Fig. 4, is represented the treble star in the left fore foot of the constellation Monoceros, one of the most beautiful objects of the kind in the heavens.

The *Beta*, in the constellation Lyra, or the Harp, is quadruple, white, but three of them a little inclined to red.

* We are not told his manner of counting.

The *Lambda* in *Orion* is quadruple. More properly, it is a double star with two stars at a small distance. The double star is unequal; the largest white, the smallest a pale rose color.

A catalogue of the principal double stars may be seen in Dr. Brewster's supplement to Ferguson. Its insertion here would far exceed the limits designed for this compend.

Several stars have appeared for a time in the heavens, and then disappeared. In ancient catalogues, stars are enumerated, which are not now to be seen, even by the powerful instruments of modern astronomy. Others are now visible, which seem not to have been noticed by the ancients.

A new star was discovered by Cornelius Gemma, in 1572, in the chair of Cassiopeia. It surpassed Sirius in brightness and magnitude. To some eyes it appeared larger than Jupiter; and might be seen at mid-day. It afterwards gradually decreased, and, after sixteen months, entirely disappeared.

In 1596, the *Stella Mira*, or wonderful star, in the neck of the whale, was observed by Fabricius. It seemed alternately to vanish and reappear seven times in six years. During this time, however, it is said never to have been entirely extinct.

In 1600, a changeable star, in the neck of the Swan, was observed by Jansenius. The same was observed, and its place determined, by Kepler. It was seen by Ricciolus, in 1616, 1621, and 1624. But, from 1640 to 1650, it was invisible. It had several instances of appearing and again vanishing, prior to the year 1715; when it re-appeared as a star of the sixth magnitude, its present appearance.

In 1604, a new star was discovered by Kepler and some of his friends near the head of Serpentarius. It exhibited a bright and sparkling appearance, beyond any they had before seen. Assuming the different colors of the rainbow, it appeared every moment changing, ex-

cept near the horizon, where it generally appeared white. It was near Jupiter in October of that year, and surpassed that planet in magnitude, but disappeared before the following February.

Several other stars have appeared, vanished, and reappeared ; some of them in regular succession. Such changeable stars may be suns, having extensive spots. Stars of this kind, by a regular rotation on their axes, may alternately present their dark and luminous sides. "Maupertuis is of opinion, that some stars, by their prodigious quick rotation on their axes, may not only assume the figure of oblate spheroids, but, by their great centrifugal force, arising from such rotation, they may become of the figure of millstones, or reduced to flat circular plates, so as to be quite invisible, when their edges are turned towards us ; as Saturn's ring is in such positions. But when any eccentric planets or comets go round any flat star, in orbits much inclined to its equator, the attraction of the planets or comets, in their perihelia, must alter the inclinations of that star ; on which account it will appear more or less large and luminous, as its broad side is more or less turned towards us."—*Ferguson*.

The propriety of the term *fixed*, as applied to the stars, seems rendered at least doubtful by the observations of modern astronomers. An advancement of the solar system, in absolute space, is now considered certain. It was observed by Halley and Cassini. The first explanation of it was given by Mayer. But, to point out the region in the heavens to which the solar system is advancing, was reserved to Dr. Herschel. "He has examined this subject with his usual success, and has certainly discovered the direction in which our system is gradually advancing. He found that the apparent proper motion of about forty-four stars out of fifty-six, is very nearly in the direction which would result from a motion of the Sun towards the constellation Hercules, or, more accurately, to a place in the heavens,

whose right ascension is $250^{\circ} 52' 30''$, and whose north polar distance is $40^{\circ} 22' 7''$.

The stars, according to their magnitude, have been arranged into six classes or orders. The largest are called *stars of the first magnitude*; next to these are those of the *second magnitude*; thus decreasing to the sixth. Of course, the least stars belong to the sixth magnitude. Sometimes, however, in modern, and even popular works, we find allusion to stars of the seventh or eighth magnitude. Considerable difference may be perceived in stars of the same class, some being much larger and more brilliant than others.

The arrangement of stars into magnitudes, was made long before the invention of telescopes. Stars unseen without the assistance of these, are called *telescopic stars*.

Another happy arrangement of the stars has been handed down to us from great antiquity. By a powerful imagination, the early cultivators of astronomy conceived companies of stars as having the form of certain animals, or other sensible objects: and hence they divided the starry sphere into constellations, each including stars of different magnitudes. According as the forms appeared to their imagination, they applied names to the different constellations. Thus one constellation was called *Leo*, another *Boötes*, and another *Orion*. Stars not included in any constellation are called *unformed stars*.

The animal, or other object of each constellation, is represented on the celestial globe, and the proportion of the stars belonging to each, denoted by the letters of the Greek alphabet, according to the plan adopted by Bayer, a German, in his *Uranometria*, a large celestial atlas. Thus, the largest star of the constellation is denoted by *Alpha*, the second by *Beta*, the third by *Gamma*, and thus on in alphabetical order.

The classing of stars, however chimerical, is of vast importance, as it enables the astronomer to designate the

place of a star, a planet or a comet, at any time, as easily as a geographer can that of a hamlet or a town.

In Plate vii, figures 1, 2, 3, 4, and 5, may be seen Cygnus, the Swan ; Phenix, the Phenix ; Piscis Australis, the Southern Fish ; Leo, the Lion ; and Crux, the Cross, contracted in size from the same on a common celestial globe. From these the student may form some idea of that imagination, by which the stars were arranged into constellations. Probably in Leo, or any other constellation viewed in the heavens, he will discover but little similarity between the figure presented by the stars, and the animal or other object by which they are represented.

Forty-eight of the constellations are reckoned ancient. Of these, 12 are in the zodiac, 21 to the north, and 15 to the south of it. The whole number of constellations has been reckoned 92. Of these, 12 are in the zodiac, 35 are north, and 45 south of that circle.

In each part of the following table, the ancient constellations are placed first.

CONSTELLATIONS IN THE ZODIAC.

Aries, the Ram.
Taurus, the Bull.
Gemini, the Twins.
Cancer, the Crab.
Leo, the Lion.
Virgo, the Virgin.

Libra, the Scales.
Scorpio, the Scorpion.
Sagittarius, the Archer.
Capricornus, the Goat.
Aquarius, the Water-bearer.
Pisces, the Fishes.

CONSTELLATIONS NORTH OF THE ZODIAC.

Ursa Minor, the Little Bear.
Ursa Major, the Great Bear.
Draco, the Dragon.
Cepheus.
Boötes.
Corona Borealis, the Northern Crown.
Hercules.
Lyra, the Harp.
Cygnus, the Swan.
Cassiopeia, the Lady in her Chair.
Perseus.
Auriga, the Wagoner.
Serpentarius, the Serpent-bearer.
Serpens, the Serpent.
Sagitta, the Arrow.
Aquila, the Eagle.
Antinous.
Dolphinus, the Dolphin.
Equi Sectio, the Horse's Head.

Pegasus, the Flying Horse.
Andromeda.
Triangulum, the Triangle.
Canes Venatici, the Greyhounds.
Cor Caroli, the Heart of Charles.
Triangulum Minus, the Little Triangle.
Musca, the Fly.
Lynx.
Leo Minor, the Little Lion.
Camelopardalis, the Camelopard.
Mons Maenalus, the Mountain Mena-
 lus.
Scutum Sobieski, Sobieski's Shield.
Hercules cum Ramo et Cerbero.
Taurus Poniatowski, Poniatowski's
 Bull.
Vulpes et Anser, the Fox and the
 Goose.
Lacerta, the Lizard.

CONSTELLATIONS SOUTH OF THE ZODIAC.

Cetus, the Whale.
Orion.
Eridanus.
Lepus, the Hare.
Canis Major, the Great Dog.
Canis Minor, the Little Dog.
Argo.
Hydra, the Water-Serpent.
Crater, the Cup.
Corvus, the Raven.
Centaurus, the Centaur.
Lupus, the Wolf.
Ara, the Altar.
Corona Australis, the Southern Crown.
Piscis Australis, the Southern Fish.
Phenix.
Officina Sculptoria, the Engraver's
 Shop.
Hydrus, the Water-Snake.
Furnax Chemica, the Chemical Fur-
 nace.
Horologium, the Time-keeper.
Reticulus Rhomboidalis.
Orado vel Zephrus, the Sword-Fish.
Cela Præstelis, the Engraver's Tool.

Columba Noachi, Noah's Dove.
Equuleus Pictorius, the Painted Colt.
Monoceros, the Unicorn.
Chamæleon.
Pycis Nautica, the Mariner's Compass.
Piscis Volans, the Flying Fish.
Sextans, the Sextant.
Robur Carolinum, the Royal Oak.
Machina Pneumatica, the Wind In-
 strument.
Crociæ et Crucero.
Apis Musca, the Bee or Fly.
Apus vel Avis, the Bird of Paradise.
Circinus, the Compass.
Quadræ Euclidis, Euclid's Square.
Triangulum Australe, the Southern
 Triangle.
Telescopium, the Telescope.
Pavo, the Peacock.
Indus, the Indian.
Microscopium, the Microscope.
Octans Hadleianus, Hadley's Octant.
Grus, the Crane.
Toucan, the American Goose.

Prior, in his Lectures, makes the whole number of constellations 105; 12 in the zodiac, 38 north, 55 south. But it may be doubted, whether increasing the number of constellations, by the addition of those that are small and unimportant, can be beneficial to the student in understanding the geography of the heavens.

The Galaxy.

The Galaxy, or *Milky Way*, is a luminous zone in the heavens. The beautiful cloudy whiteness, by which it is distinguished, is found by modern astronomers to proceed from the collected rays of innumerable stars not discernible by the naked eye. "That the milky way," says Dr. Herschel, "is a most extensive stratum of stars of various sizes, admits no longer of the least doubt."

A *group* of stars is a collection of them of any figure, closely compressed together, like the trees in a crowded forest.

Clusters of stars are regarded by Dr. Herschel among the most magnificent objects in the heavens. They differ from groups in their beautiful and seemingly artificial arrangement. (Plate vii. Fig. 6.)

Nebulæ are light spots in the heavens, sometimes denominated *cloudy stars*. (Plate vii. Fig. 7.) Some of them are found to be clusters of telescopic stars. The most noted nebula was discovered by Huygens, in 1656. It is between the two stars in the sword of Orion. In one part of it, (Plate viii. Fig. 1,) a bright spot upon a dark ground seems to be an opening into a brighter and more distant region. *Nebulæ* were discovered by Dr. Halley and others. "But to Dr. Herschel," says Enfield, "are we indebted for catalogues of 2000 *nebulæ* and clusters of stars, which he himself has discovered." Dr. Brewster says, "2500."

What an astonishing view of the works of creation is opened upon us by the night! With wonder and delight, we greet the return of day. The beauty, and even the sublimity, of this world are lighted up to us by the splendor of the morning. But how surpassed are these by the infinite grandeur presented to our view by the *nocturnal* heavens! To the night we are indebted

for the most exalted conceptions we can form of the immensity and sublimity of Jehovah's works. We cannot contemplate them without the most profound awe! We behold, not a solitary world, but a system of worlds, kept in perpetual harmony by the Sun; not one sun and one system only, but millions of suns and of systems, ranged in endless perspective, all revolving in harmonious order! How inconceivably great, and wise, and good, must be the **AUTHOR AND GOVERNOR OF SUCH A UNIVERSE!**

Why are the stars called *fixed stars*? What reason have we to consider their distance immense? What does Mr. Ferguson think may be the distance of the nearest star? How long would a cannon ball be in flying to it? Why must we conclude the stars shine by their own light? What are the *fixed stars* now considered? How may they be distinguished from planets? What number of stars is visible to the naked eye in either hemisphere? What are most of those bright spots which are taken for stars in a clear evening? What number of stars does the British catalogue contain? By improved telescopes, how is the number found to be? What number of stars did Dr. Herschel see pass his telescope in a quarter of an hour? How do some stars, seemingly single to the naked eye, appear viewed through a good telescope? What is a binary sidereal system? Can you mention some stars which are double, treble, or quadruple? Do stars seen at any time ever disappear? Can you give the particulars of some such stars? What was remarkable in the new star discovered by Kepler in 1604? What may stars of this kind be? What was the opinion of Maupertuis? What renders doubtful the term *fixed*, as applied to the stars? Who observed an advancement of the solar system in absolute space? Who gave the first explanation of this? Who pointed out the part in the heavens to which the solar system is advancing? How have the stars been arranged into classes or orders? Was the arrangement of the stars into magnitudes before or after the invention of telescopes? What other arrangement of the stars has been handed down to us from antiquity? What did the ancients conceive companies of stars as having? How did they apply names to constellations? Can much similarity be perceived between the figure presented by the stars in a constellation and the animal or other object by which it is represented? How many constellations are reckoned ancient? How many constellations are there? How many in the zodiac? how many north, and how many south? How many constellations does Prior enumerate in his Lectures, in the zodiac, north and south? What is the galaxy? From what does the whiteness of the galaxy proceed? What is a group of stars? What are clus-

ters of stars? What are nebulae? When did Huygens discover the most noted nebula? Where is it? To whom are we indebted for extensive catalogues of nebulae and clusters of stars? Which opens on us the most sublime view of the Creator's works, the day or the night? Can we form any idea of the immensity of Jehovah's works?

CHAPTER XIII.

Refraction.

REFRACTION of light is the incurvation of a ray from its rectilinear course. In passing obliquely from one medium into another of different density, a ray is turned towards the perpendicular, drawn to the surface of the denser medium; but it is turned from the perpendicular drawn to the surface of a rarer medium, in passing from one more dense.

Refraction elevates a body, or makes it appear above its true place. An object always appears in the last direction in which a ray of light from it passes to the eye of the observer; though before it may have been refracted or reflected many times. A straight rod partly immersed in water appears crooked, when viewed obliquely to the surface of the water. The rays of light coming from the part immersed are refracted, or turned out of their course, in coming into the air, a rarer medium. The eye, therefore, viewing that part in the direction of the ray after refraction, sees it above its true place. Put a piece of money into a bowl, and retire till the money is just hidden by the edge of the bowl; let an attendant pour water into the bowl, the piece will rise into view. To the eye at A, (Plate vi.

Fig. 9,) the money at a is hidden by the edge of the bowl, but a ray of light from the piece immersed in water is refracted at the surface, and passes in the direction b A. Hence it becomes visible, appearing at b .

A ray of light passing from one medium into another, in a line perpendicular to the intervening surface, suffers no refraction. It is true, that, when a person looks into a pail, or other vessel of water, the bottom seems elevated some distance above the ground or bench on which the vessel stands. But it must be remembered, that no single point of the surface is, in such a view, perpendicular to both eyes. And when the observer uses but one eye, from a single point only does a ray of light pass perpendicularly to that eye. In such case, the imagination gives an elevated appearance to the whole. In wading a river, the water by you appears about its true depth; but at a little distance forward, it appears more shallow than it will be found on trial, the bottom seeming elevated by refraction. No doubt this has often been the cause of drowning.

The light of heavenly bodies is refracted, in coming to us, by the atmosphere of the Earth. This refraction is greatest at the horizon. Decreasing upwards, it becomes nothing at the zenith. When a medium is equally dense in every part, the refraction is at the surface. But it is not so in a varying medium. The atmosphere of the Earth decreases in density from the surface upward to its utmost height. A ray of light, therefore, must be more and more refracted, and pass in a curvilinear course through the atmosphere.

Refraction brings a heavenly body into view, when it is below the horizon. Let $A B C$, (Plate v. Fig. 10,) be a part of the Earth's atmosphere; $B F$, the sensible horizon to an observer at B ; D , a place of the Sun below the horizon. Should a ray of light, passing in the direction $D F$, strike the atmosphere at F , it would be refracted by the increased density of the air all the way

from F to the surface of the Earth at B, and would present the Sun in the line of its last direction B E. The Sun would, therefore, appear in the horizon, while it is below that circle.

The density of the air and the refracting power are increased by cold. The higher the latitude, therefore, in general, the greater the refraction. We are told by Mr. Ferguson, that, in 1596, some Hollanders wintered in Nova Zembla, and that the Sun arose to them seventeen days sooner than, by calculation, it would have been above the horizon. Though refraction increases the length of the day over the night more in high latitudes than in those that are near the equator, yet, from the principle, it must be perceived, that the day is increased in all latitudes. The excess of the day over the night by refraction, exclusive of twilight, in latitude 43° has been computed at about six minutes, three in the morning and three in the evening.

The refraction of the atmosphere is sometimes the cause of a curious phenomenon, the Sun and Moon both visible, when the Moon is eclipsed by the Earth's shadow. An instance of this kind, observed at Paris in 1750, is mentioned by Mr. Phillips in his *Astronomy*.

The disk of the Sun or Moon, when in or near the horizon, appears elliptical. The lower limb being more elevated by refraction than the upper, not only by the atmosphere itself, but often by floating vapor, the outline of the disk must be changed from a circle to an elliptical form.

What is refraction of light? In passing obliquely from one medium into another of different density, how is a ray turned? Does refraction make a body appear above or below its true place? In what direction does an object always appear? Why does a rod immersed partly in water appear crooked? What is the cause that a piece of money at the bottom of a bowl will appear to rise, on water being poured into the bowl? Is a ray of light affected by refraction in passing perpendicularly from one medium into another? What refracts a ray of light in coming from a heavenly body to us? Why does a ray of light pass in a curvilinear course through the atmosphere of the Earth? Why can a heavenly body

be seen by us when it is below the horizon? What effect has cold on the refracting power of the air? What curious circumstance is related by Mr. Ferguson? What excess of the day over the night, is it computed, refraction gives in latitude 43° ? Of what curious phenomenon is the refraction of the atmosphere sometimes the cause? Why does the disk of the Sun or Moon, when in or near the horizon, appear elliptical?

CHAPTER XIV.

Twilight.

TWILIGHT, or crepusculum, is the light of the morning before sun-rising, and of the evening after sun-setting. It is the result of refraction. The atmosphere of the Earth extends about 45 miles in height; or, at that distance from the Earth's surface, it is sufficiently dense to refract the rays of the Sun. Hence, when the Sun is about 18° below the horizon, the morning twilight begins, and the evening twilight ends. The evening twilight is said, however, to be longer than that of the morning. The elevation of the atmosphere by the heat of the day and the vapor exhaled by rarefaction, may, by affecting the refracting power of the air, prolong the evening twilight.

The continuance of twilight must increase with the distance from the equator, and be very long in high latitudes. At the poles, the Sun is never more than about $23^{\circ} 28'$ below the horizon. If there be polar inhabitants, therefore, they must be blessed with a long twilight. To them it must be more than 50 days after the Sun sets, before it will be 18° below the horizon, and, on its return, the same time, after it approaches within 18° , before it will be above the horizon.

The immense benefit of the atmosphere must be contemplated with admiration. Not only, by the chemical operations of air, does it cause our blood to flow, and diffuse warmth through our bodies ; but, by its reflecting and refracting powers, it gives beauty to the day. It gives also an easy and pleasing transition from night to day, and from day to night, and enlarges the borders of the day even into the regions of night. Astronomers generally concur with Dr. Keill, "that it is entirely owing to the atmosphere, that the heavens appear bright in the day time. For without it, only that part of the heavens would be luminous in which the Sun is placed ; and, if we could live without air, and should turn our backs to the Sun, the whole heavens would appear as dark as in the night. In this case, also, we should have no twilight, but a sudden transition from the brightest sunshine to dark night, immediately upon the setting of the Sun, which would be extremely inconvenient, if not fatal to the eyes of mortals."

What is twilight? How high is the atmosphere? How far below the horizon is the Sun when the morning twilight begins, and the evening twilight ends? Which have the longest twilight, the people near the equator, or those in high latitudes? How long must the twilight be at the poles? Can you name some particular benefits derived to us from the atmosphere? According to Dr. Keill, what would be the consequence of our being without an atmosphere?

CHAPTER XV.

Latitude and Longitude.

SEC. I. LATITUDE.

LATITUDE, as before stated, is the distance north or south from the equator. It is reckoned on the meridian in degrees; which, like those of all other circles, are subdivided into minutes, and again into sexagesimal parts. The centre of the meridian, like that of the equator, and other great circles of the globe, is considered at the centre of the Earth.

The great circles of the globe, extended into the visible heavens, are considered as celestial circles, always lying in the same plane with those on the Earth. The position of the heavenly bodies, therefore, in regard to these circles, may be used in determining the latitude and longitude of places.

The latitude of a place may be determined by finding the distance of its zenith from the celestial equator. If, therefore, the zenith distance of a heavenly body, and its declination, be known, the latitude of the place of observation may be ascertained.

The declination of a heavenly body, as before defined, is its distance north or south from the celestial equator. The zenith distance of a heavenly body may be obtained by observing its meridian altitude, or by two altitudes. Four corrections are required in finding the altitude of the Sun or Moon; *semi-diameter*, *depression of the horizon*, *parallax*, and *refraction*. [For tables to find these, see the author's larger work, and other works on astronomy.] The semi-diameter and parallax of a planet can be but a few seconds. They are imperceptible in a star.

Suppose that, on the 4th of July, 1831, the Sun's declination was found to be $22^{\circ} 55' 39''$ north, when it passed the meridian of New York; and at that time the Sun's true zenith distance was found to be $17^{\circ} 46' 21''$ south; what is the latitude of that city?

Declination	$22^{\circ} 55' 39''$
Zenith distance	$17^{\circ} 46' 21''$
Answer	$40^{\circ} 42' 0$

If Arcturus, the noble star mentioned in the book of Job, be in $20^{\circ} 20'$ north declination, as placed on the British celestial globe, and be observed to pass the meridian of Boston $22^{\circ} 3'$ south of the zenith, what is the latitude of the city?

Declination	$20^{\circ} 20'$
Zenith distance	$22^{\circ} 3'$
Answer	$42^{\circ} 23'$

With a little attention, the student may easily determine; whether he ought to add or subtract in making these calculations. If, in the last example, the declination had been $20^{\circ} 20'$ *south*, the zenith distance would have been $62^{\circ} 43'$, and the declination must have been subtracted to find the latitude of the place.

The latitude of a place may be determined by observing the altitude of its elevated pole. This altitude is always equal to the latitude of the place of observation. At this time, the north pole of the Earth points nearly to a particular star, well known as the *north or pole star*. According to Dr. Flint, in his Survey, the declination of this star in 1810 was $88^{\circ} 17' 28''$, with an annual increase of $19\frac{1}{4}''$. Hence its declination on the 1st day of January, 1831, was $88^{\circ} 24' 17''$, and its distance from the pole, $1^{\circ} 35' 43''$. Let the altitude of this star above and below the pole be taken. Half the sum of these altitudes, added together, is the altitude of the pole, and equal to the latitude of the place.

Semi-diameter and depression of the horizon have

been mentioned, as necessary corrections in determining latitude, and not explained in separate articles.

The semi-diameter of a heavenly body is the angle under which the semi-diameter of the body appears at the Earth. The distance of the limb being taken in ascertaining the altitude of the Sun or Moon, the semi-diameter is necessarily applied, in order to reduce it to the centre of the body.

Depression of the horizon is caused by the eye of the observer being elevated. When a man stands uprightly, he looks down on the horizon, which touches the Earth at his feet. It must be apparent, that, the higher the eye is elevated, the farther below the horizon, touching the surface of the Earth beneath it, may a heavenly body be seen.

SECTION II. *Longitude.*

Longitude, on the Earth's surface, is the distance east or west from some fixed meridian, assumed as first. Like latitude, it is reckoned in degrees, minutes and sexagesimal parts.

The best method of determining longitude has long been an object of inquiry by the mariner and the geographer, the mechanic, the statesman, and the philosopher.

Philip III. of Spain, we are informed, offered a reward of a hundred thousand crowns for the discovery of longitude. The States of Holland, then the rival of Spain, soon after followed the example. During the minority of Lewis XV., the Regent of France offered a great reward for the discovery of longitude, at sea. About the year 1675, in the time of Charles II. of England, the royal observatory was built at Greenwich. Mr. Flamstead was appointed astronomer royal. Instructions were given to him and his successors, "that they should apply themselves with the utmost care and diligence to rectify the tables of the motions of the

heavens, and the places of the fixed stars, in order to find out the so much desired longitude at sea, for the perfecting of the art of navigation."

In 1714, the British parliament offered £10,000 for the discovery of longitude, if the method determined it to 1° ; £15,000 if it determined to $40'$; and £20,000 if it determined to $30'$; with a proviso, that if such method extended but to 80 miles adjoining the coast, the proposer should have but half the reward. On this act, Mr. John Harrison received the premium of £20,000, for his time-keeper. Several other acts were passed in the reigns of George II. and George III. for the encouragement of finding longitude. An act passed in 1774, said to be the last of that government on the subject, repealing all the former acts. This act diminishes the premium to half the first great offer.

The United States have not been inattentive to the subject of longitude; so far, at least, as respects the establishment for themselves of a first meridian. In the year 1809, Mr. Lambert of Virginia presented to congress a memorial on the subject of longitude. He commences by stating, "that the establishment of a first meridian for the United States of America, at the permanent seat of government, by which a further dependence on Great Britain, or any other foreign nation, for such a meridian, may be entirely removed, is deemed to be worthy the consideration and patronage of the national legislature." An interesting report on this memorial was made in March, 1810, by a select committee of the house of representatives, of which Mr. Pitkin, of Connecticut, was chairman. An extract from this report may deserve a place even in a compendium of astronomy.

"The committee have deemed the subject worthy the attention of congress, and would therefore beg leave to observe, that the necessity of the establishment of a first meridian, or a meridian which should pass through some particular place on the globe, from which geogra-

phers and navigators could compute their longitude, is too obvious to need elucidation.

"The ancient Greek geographers placed their first meridian to pass through one of the islands, which by them were called the Fortunate Islands, since called the Canaries. Those islands were situated as far west as any islands that had then been discovered, or were known by ancient navigators in that part of the world.

"They reckoned their longitude east from Hera, or Junonia, supposed to be the present island of Tenerife.

"The Arabians, it is said, fixed their first meridian at the most westerly part of the continent of Africa. In the fifteenth and sixteenth centuries, when Europe was emerging from the dark ages, and a spirit of enterprise and discovery had risen in the south of Europe, and various plans were formed, and attempts made, to find a new route to the East Indies, geographers and navigators continued to calculate longitude from Ferro, one of the same islands, though some of them extended their first meridian as far west as the Azores, or Western Islands.

"In more modern times, however, most of the European nations, and particularly England and France, have established a first meridian to pass through the capital, or some place in their respective countries, and to which they have lately adapted their maps, charts, and astronomical tables.

"It would, perhaps, have been fortunate for the science of geography and navigation, that all nations had agreed upon a first meridian, from which all geographers and navigators might have calculated longitude; but as this has not been done, and, in all probability, never will take place, the committee are of opinion, that, situated as we are in this western hemisphere, more than three thousand miles from any fixed or known meridian, it would be proper, in a national point of view, to establish a first meridian for ourselves; and

that measures should be taken for the eventual establishment of such a meridian in the United States.

"In examining the maps and charts of the United States, and the particular states, or their sea-coasts, which have been published in this country, the committee find that the publishers have assumed different places in the United States, as first meridian. This creates confusion, and renders it difficult, without considerable calculation, to ascertain the relative situation of places in this country. This difficulty is increased by the circumstance, that, in Louisiana, our newly-acquired territory, longitude has heretofore been reckoned from Paris, the capital of the French empire.

"The exact longitude of any place in the United States being ascertained from the meridian of the observatory at Greenwich, in England, a meridian with which we have been conversant, it would not be difficult to adapt all our maps, charts, and astronomical tables, to the meridian of such place. And no place, perhaps, is more proper than the seat of government."

The memorial, the report of the committee, and other papers, were afterwards referred to Mr. Monroe, then secretary of state, and late president of the United States. His opinion fully accorded with that of the committee, in favor of establishing a first meridian for the United States, and that it should be at Washington, the seat of government.

The subject was afterwards referred to another committee of the house of representatives, of which Dr. Samuel L. Mitchill of New York was chairman. The report of this committee was in full accordance with the preceding sentiment, and in favor of the establishment of a first meridian at the seat of government.

To these high authorities, that of the illustrious Washington may be added, as stated by Mr. Lambert, in 1821, in his address on the subject to the president of the United States.

"The illustrious personage, by whose name the me-

tropolis of the American Union has been designated, unquestionably intended, that the capitol, situated at, or near, the centre of the District of Columbia, should be a first meridian for the United States, by causing, during the first term of his presidency, the geographical position of that point, in longitude $0^{\circ} 0'$, and its latitude, $38^{\circ} 53'$ north, as found by Mr. Andrew Ellicott, to the nearest minute of a degree, to be recorded in the original plan of the city of Washington."

Relative or apparent time differs four minutes for a degree, or one hour for every 15° of longitude. To the east, it is later; to the west, earlier. When it is noon with us, it is one, P. M., 15° east; eleven, A. M., 15° west. Washington, according to Mr. Lambert, is $76^{\circ} 55' 30''$ west of Greenwich. It is 6 h. 52 m. 18 s., A. M., at Washington, when it is noon at Greenwich. Boston is $159^{\circ} 32'$ west of Calcutta. When it is noon at Boston, it is 10 h. 38 m. 8 s., P. M., at Calcutta. If, therefore, by an exact time-keeper, or observation on the heavenly bodies, the time of day at the meridian, from which longitude is reckoned, and also the time at the place of observation, can be known, the difference converted into motion will show the longitude.

A good time-keeper, clock or watch, forms one method of computing longitude. Such time-keeper, set for any meridian, will not, when carried east or west, correspond with the apparent time. But its difference from the time at the place of observation, turned into motion, would, if true, give the longitude. If a ship, sailing from London to Boston, should set a watch for the meridian of London $6'$ west of Greenwich, such watch, if perfectly accurate, would give the time 4 h. 43 m. 25 s., P. M. when the Sun is on the meridian at Boston. No clock or watch, however, yet invented, has been found entitled to perfect dependence. Even the time-keeper of Mr. William Harrison was found subject to considerable error, when tried at the royal observatory by Dr. Maskelyne; though it had

made a voyage from England to Barbadoes and back again, varying but 54 seconds in 156 days, or, as was thought, with proper allowance, only 15 seconds in that time.

The eclipses of Jupiter's satellites, happening very often, form an excellent method of determining longitude on land. Like those of the Moon, they are seen at the same absolute time in all places, where they are visible. The difference in relative time, then, will show the longitude. Suppose an eclipse of the 4th satellite of Jupiter be set in the Nautical Almanac published for Greenwich at 4 h. 25 m., A. M., on a particular day, and the same is observed in the United States at 11 h. 17 m. 18 s., P. M., of the preceding day. What is the difference of longitude?

$$\begin{array}{r}
 4 \text{ h. } 25 \text{ m. } 0 \text{ s.} \\
 -11 \text{ h. } 17 \text{ m. } 18 \text{ s.} \\
 \hline
 5 \quad 7 \quad 42
 \end{array}$$

In making this subtraction, it will be perceived, from the nature of the case, that 12 must be added to the hours of the minuend, or upper number. Convert 5 h. 7 m. 42 s. into motion, by allowing 15° for each hour, 1° for every 4 minutes, and 1 minute for every 4 seconds, and so on for thirds, you have the difference of longitude $76^\circ 55' 30''$.

It is said, the difficulty of observation at sea renders eclipses of Jupiter's satellites of but little practical utility to the mariner in computing longitude.

Lunar observations form another method of determining longitude. This method is a great modern improvement in navigation. The idea is not very modern. "M. de la Lande mentions certain astronomers, who, above two hundred years ago, proposed this method, and contended for the honor of the discovery; but its present state of improvement and universal practice he very justly ascribes to Dr. Maskelyne." This last-mentioned astronomer first proposed and superintended

the construction of the Nautical Almanac. In this the angular distance of the Moon from the Sun and certain fixed stars is inserted for every third hour in the day, calculated for the meridian of Greenwich. "If, therefore, under any meridian, a lunar distance be observed, the difference between the time of observation and the time in the Almanac, when the same distance was to take place at Greenwich, will show the longitude." The stars selected for the Almanac are nine, viz. the Alpha, or first star of Aries, Aldebaran of Taurus, Pollux of Gemini, Regulus of Leo, Spica of Virgo, Antares of Scorpio, Altair of Aquila, Fomalhaut of Piscis Australis, and Markab of Pegasus. The Nautical Almanac is annually published in England by the commissioners of longitude.

For practice in finding longitude, with the necessary tables, the student is referred to Dr. Bowditch's useful work, the "Practical Navigator."

Except a small variation on account of the spheroidal figure of the Earth, degrees of latitude remain the same, or of equal length, on every part of the globe. But those of longitude decrease from the equator to the poles, where they become extinct. The number of degrees in a circle of longitude is the same in all latitudes; but the number of miles in a degree continually lessens each way from the equator. The student versed in trigonometry may be informed, that the proportion is—as radius is to the cosine of any given latitude, so is the number of miles in a degree of longitude at the equator, to the number of miles in a degree of longitude at such latitude.

The table following may be useful, not only as giving the number of miles in a degree of longitude at any distance from the equator; but for comparing geographical with statute miles, 60 geographical and $69\frac{1}{2}$ statute miles being the length of a degree of longitude at the equator.

A TABLE OF GEOGRAPHICAL AND STATUTE MILES IN A DEGREE OF LONGITUDE AT EACH DEGREE OF LATITUDE FROM THE EQUATOR.

Deg. lat.	Geog. miles.	Stat. miles.	Deg. lat.	Geog. miles.	Stat. miles.	Deg. lat.	Geog. miles.	Stat. miles.
1	59.99	69.49	31	51.43	59.57	61	29.09	33.69
2	59.96	69.46	32	50.88	58.94	62	28.17	32.63
3	59.92	69.40	33	50.32	58.29	63	27.24	31.55
4	59.85	69.33	34	49.74	57.62	64	26.30	30.47
5	59.77	69.23	35	49.15	56.93	65	25.36	29.37
6	59.67	69.12	36	48.54	56.23	66	24.40	28.27
7	59.55	68.98	37	47.92	55.51	67	23.44	27.16
8	59.42	68.82	38	47.28	54.77	68	22.48	26.04
9	59.26	68.64	39	46.63	54.01	69	21.50	24.91
10	59.09	68.44	40	45.96	53.24	70	20.52	23.77
11	58.90	68.22	41	45.28	52.45	71	19.53	22.63
12	58.69	67.98	42	44.59	51.65	72	18.54	21.48
13	58.46	67.72	43	43.88	50.83	73	17.54	20.32
14	58.22	67.43	44	43.16	49.99	74	16.54	19.16
15	57.96	67.13	45	42.43	49.14	75	15.53	17.99
16	57.68	66.81	46	41.68	48.28	76	14.52	16.81
17	57.38	66.46	47	40.92	47.40	77	13.50	15.63
18	57.06	66.10	48	40.15	46.50	78	12.47	14.45
19	56.73	65.71	49	39.36	45.60	79	11.45	13.26
20	56.38	65.31	50	38.57	44.67	80	10.42	12.07
21	56.01	64.88	51	37.76	43.74	81	9.39	10.87
22	55.63	64.44	52	36.94	42.79	82	8.35	9.67
23	55.23	63.98	53	36.11	41.83	83	7.31	8.47
24	54.81	63.49	54	35.27	40.85	84	6.27	7.26
25	54.38	62.99	55	34.41	39.86	85	5.23	6.06
26	53.93	62.47	56	33.55	38.86	86	4.19	4.85
27	53.46	61.92	57	32.68	37.85	87	3.14	3.64
28	52.98	61.36	58	31.80	36.83	88	2.09	2.43
29	52.48	60.79	59	30.90	35.80	89	1.05	1.21
30	51.96	60.19	60	30.00	34.75	90	0.00	0.00

Where is the centre of the meridian and other great circles of the Earth? Are the great circles of the globe considered as celestial circles? What may be used, in regard to these circles, in determining latitude and longitude? What two things being known, may the latitude of a place be determined? How may the zenith distance of a heavenly body be obtained? What corrections are required in finding the altitude of the Sun or Moon? How near to the pole star does the north pole of the Earth point?

Is it drawing nearer, or receding? What is meant by *semi-diameter* in these calculations? What is meant by *depression of the horizon*? Does it increase, or not, with the height of the eye? From what is longitude reckoned? What did Philip III. of Spain offer for the discovery of longitude? What other governments offered rewards for this discovery? When was the royal observatory at Greenwich built? What instructions were given to Mr. Flamsteed, the first astronomer royal, and his successors, respecting longitude? What did the British parliament offer, in 1714, for the discovery of longitude? What premium did Mr. John Harrison obtain for his time-keeper? Has the government of the United States paid any attention to the subject of longitude? Who, in 1809, presented a memorial to congress on this subject? Where, according to the committee of congress, did the ancient Greeks fix their first meridian? Where did the Arabians establish theirs? In more modern times, what have most European nations done? What would have been fortunate for the science of geography and navigation? Is it likely that all nations will agree upon the same first meridian? Are there any reasons why the United States should establish a first meridian for themselves? In the maps and charts of the United States, is longitude always reckoned from the same meridian? Through what important place ought the first meridian of the United States to pass? What was the opinion of Mr. Monroe on this subject? Where did General Washington intend the first meridian of the United States should pass? How many degrees of longitude east or west make an hour's difference in relative time? Is it earlier in the day, or later, to the east of us? How is it to the west? How can difference of longitude be ascertained by a good time-keeper? Have any time-keepers been found so accurate as to be entitled to perfect dependence? How can the eclipses of Jupiter's satellites be used for determining longitude? Can these eclipses be conveniently used at sea? Are lunar observations for finding longitude perfectly modern? To whom are we indebted for the present state and practical improvement of these observations? Who first proposed and superintended the construction of the Nautical Almanac? In this, from what is the angular distance of the Moon taken? How are lunar observations used in determining longitude? What stars are used for these observations? Do degrees of latitude differ in different places? How do degrees of longitude differ? How is the table of longitude useful?

CHAPTER XVI.

Meteors.

IN some astronomical works are to be found accounts of lightning, thunder, clouds, aurora borealis, and even of wind, rain, snow, and hail. These, though highly important, and deserving the attention of the chemist and the student in general philosophy, seem not connected with astronomy, nor deserving a place in a work intended to be exclusively astronomical.

But *aerolithes*, or *falling stones*, seem worthy of some notice, even in a compendium of astronomy. "It must be reckoned," says Rees's Cyclopædia, "among the wonders of the age in which we live, that considerable portions of these heavenly bodies are now known to have descended to the Earth. So wonderful and unexpected an event was at first received with incredulity and ridicule; but we may now venture to consider the fact as well established as any other hypothesis of natural philosophy, which does not actually admit of mathematical demonstration."

One of the earliest accounts we have of these phenomena is given by Livy, in his History of Rome. He tells us that, in the time of Tullus Hostilius, the successor of Numa, and third king of Rome, it was announced to the king and to the fathers, that it rained with stones on mount Albanus; that these stones fell from heaven not otherwise than when the winds drive the hail thick to the Earth.

Pliny mentions, that a large stone fell in Thrace, in the second year of the 78th Olympiad.

Three large stones are said to have fallen in Thrace, in the year before Christ 452.

It would be useless to dwell on the numerous ac-

counts of these phenomena handed down to us from great antiquity. But it may be proper to give a few instances of the falling of these stones in modern times, received on the authority of different authors.

A shower of falling stones, 1200, one of 120 lbs., is related to have happened near Padua, in Italy, in 1510.

April 5, 1804, a stone of this kind fell near Glasgow, in Scotland. Several gentlemen of the university well ascertained the particulars of this phenomenon.

But New England affords one of the best authenticated accounts of these wonderful stones. Professors Silliman and Kingsley visited and carefully examined every spot where it was ascertained these stones had fallen. The principal fall was within the bounds of Weston, in Connecticut; though the most northerly was in Huntingdon, on the borders of Weston. Something of the original account deserves to be extracted. "The meteor which has so recently excited alarm in many, and astonishment in all, first made its appearance in Weston, about a quarter or half past six o'clock, on Monday the 14th of December, 1807. The morning was somewhat cloudy, mingled with spots of clear, a space of 15° along the northern horizon perfectly clear; there was little or no light, except from the Moon, just setting.

"Judge Wheeler was passing through the enclosure adjoining his house, with his face towards the north, and his eyes on the ground, when a sudden flash across the northern sky made him look up; he immediately discovered a globe of fire, passing behind the first cloud, which was very dark, and obscured the meteor. In this situation, its appearance was distinct, like the Sun seen through a mist. Its progress was not so rapid as that of common meteors and shooting stars. When it passed the clear sky, it flashed with a vivid light, not so intense as lightning in a thunder-storm, but like what is called *heat lightning*. Its surface was apparently convex. When not too much obscured by clouds, a conical train of paler light attended it waving, and in length

about 10 or 12 diameters of the body. In the clear sky, there was a brisk scintillation about it, like a fire-brand carried against the wind. It disappeared about 15° short of the zenith, and the same number west of the meridian. It did not vanish instantaneously, but grew fainter, as a red-hot cannon ball would do, cooling in the dark, only much more rapidly.

"About 30 or 40 seconds after this, three loud and distinct reports, like those of a four-pounder, near at hand, were heard. They succeeded each other rapidly, and did not occupy above three seconds. Then followed a continual rumbling, like a cannon-ball rolling over a floor, sometimes louder and sometimes fainter."

There were six places where stones fell on this occasion; the most remote, nine or ten miles from each other. One fell on a rock of granite with a loud report. It was broken into fragments, thrown to the distance of 30 feet, some part reduced to powder. One mass of this fall was found sunk two feet below the surface of the ground. Of the masses found, two weighed 35 lbs. each; one, 25 lbs. From the fragments found of one, it was thought it must have weighed nearly 200 lbs.

A great similarity is found in these stones, when examined chemically, in different parts of the world, where they had fallen. But they are very different from the other stones on the surface of the Earth.

Much speculation has been excited respecting the origin of the *aerolithes*. Prior tells us, "The most prevalent opinion among modern philosophers is, that they are concretions actually formed in the atmosphere itself." But that such solid and weighty bodies should be formed in the *rare* medium of the atmosphere, would be more wonderful than the falling stones themselves. Some have supposed they originate in the asteroids.

Perhaps the most probable opinion is that of La Place, "that the stones are projected by lunar volcanoes

within the sphere of terrestrial attraction." The Moon is but 240,000 miles from the Earth. The force of attraction in different bodies is as the quantity of matter. Of this, that of the Earth is to that of the Moon as 1 to .025. Hence the neutral ground between the two bodies must be vastly nearer the Moon than the Earth. Whenever matter thrown up by a volcano from the Moon, passes this ground, it must irresistibly be drawn to the Earth.

The luminous meteors usually denominated *shooting stars* seem different in their origin, and to be of species different from *aerolithes*, or falling stones. In some instances, in which these meteors have appeared in immense numbers, for many hours in succession, and over an extensive region, no falling stones have been discovered, nor any traces been found where they have marked the Earth.

Several noted instances of these meteors have occurred in modern times. An account of one is given by Humboldt, witnessed by himself and Bonpland at Cumana in South America. "The night of the 11th of November, 1779, was cool and extremely beautiful. Toward the morning, from half after two, the most extraordinary luminous meteors were seen towards the east. Bonpland, who had risen to enjoy the freshness of the air in the gallery, perceived them first. Thousands of bolides, fireballs, and falling stars, succeeded each other during four hours. Their direction was very regular from north to south. They filled a space in the sky extending from the true east 30° towards the north and south; some of them attained a height of 40° , and all exceeded 25° or 30° . There was very little wind, and no trace of clouds to be seen."

Phenomena similar to those seen by Humboldt were extensively observed on the Atlantic ocean and the gulf of Mexico, on the 12th of November, 1799. The following account of these has been extracted into our papers from the Newburyport Herald of that year. It was given by Captain Woodman, of the brig Nymph.

“On my passage home from the island of St. Domingo, being in lat. 29° lon. 71° , on the 12th of November, at half past one o'clock in the morning, the weather being very clear and pleasant, the wind to the eastward, the moon near the full, and shining very bright, observed the stars to shoot in great numbers from every point of the compass; and at 2 o'clock the whole atmosphere appeared to be full of stars,—I may say thousands of thousands,—shooting and blazing in all directions—in a most extraordinary and alarming manner, and so continued till day-light. On my arrival at the Vineyard, I met with several masters of vessels, who were on their passage at the same time, and said, that the stars made the same appearance to them, on the night above mentioned, though they were then several degrees to the northward of me.” This account was dated Newburyport, December 20, 1799.

These phenomena of November 12th, 1799, were witnessed by Mr. Ellicott, when a commissioner to settle the boundary line between the United States and the Spanish possessions in North America. He describes them as “grand and awful. The whole heavens appeared as if illuminated with sky-rockets, which disappeared only by the light of the Sun after day-break. The meteors, which, at any one instant of time, appeared as numerous as the stars, flew in all possible directions, except from the Earth.”

Captain Hammond, and his crew, when at Mocha in Arabia, on the 12th of November, 1832, witnessed a similar display of luminous meteors, and described them in similar language.

The citizens of these United States will long remember the night of the 12th, or the morning of the 13th of November, 1833. The brilliant exhibition of luminous meteors, which adorned the canopy from the St. Lawrence to the gulf of Mexico, and from the Atlantic to the Rocky mountains, perhaps has never been surpassed in the time of its continuance, or in the richness and grandeur of its appearance.

The display seems to have commenced earlier, as seen from the southern, than from the northern sections of the Union. The following account is extracted from the Charleston Mercury of November 14th, 1833.

"Those who were up before the dawn yesterday witnessed a most glorious sight, one glance at which were worth ten years of common life. The temperature of the day before had been oppressive, the mercury ranging as high as 78 degrees. At night, the atmosphere became cooler, but not so much as to make a fire necessary for comfort. About 10 o'clock, P. M., shooting stars were observed to succeed each other with unusual frequency, and continued to appear at short intervals during the night. But at about 3 o'clock in the morning, the wind, which had been from the west, having changed, and blowing with some freshness from the north-east, there was a burst of splendor throughout the firmament, and its entire concave was thronged with innumerable meteors, streaming athwart each other towards the horizon in every quarter, leaving long trains of light, as if millions of rockets were incessantly exploding. The literal shower of stars continued till day-light, exploding in glittering confusion, as if the whole starry host were reeling madly from their spheres.

"While this grand and beautiful spectacle lasted, a permanent light, as strong as moonlight, was thrown through the windows of our chambers, and, although the sky was without a cloud, there were flashes, from time to time, of the most vivid lightning. The unusual light roused many from their beds, some supposing that the city was on fire. While every spectator must have gazed with feelings of awe, some were astonished into the liveliest terror."

There is a striking coincidence of expression in the description of these phenomena in different and distant parts of the country. How far they were visible beyond the limits of the United States is not yet ascertained. They are described as having appeared splendid at St. George's Bank, three hundred miles from the coast.

The astonishing displays of meteors seen at different times, 1779, 1799, 1832, and 1833, all appeared at the same time of the year, or within a single day of the same time. This is worthy of notice and philosophic inquiry.

The cause of these phenomena, these *showers* of luminous meteors, evidently distinct from aerolithes, seems now demanded from every quarter, by the wise and the simple, the learned and the unlearned. Many hypotheses have been formed on the subject. Dr. Halley conjectured "that a stratum or train of inflammable vapor, gradually raised from the Earth, and accumulated in an elevated region, suddenly took fire, and, burning like a train of gunpowder, exhibited the meteoric phenomena." The late President Clap of New Haven supposed fiery meteors to be terrestrial comets, revolving about the Earth. But his attention must have been fixed on others, and not on these *showers* of meteors. A learned professor, wishing for more information concerning the late meteors, thinks "it evident, that the point from which the fireballs emanated was beyond the limits of our atmosphere; that the balls were projected obliquely into the atmosphere; that they were not at first luminous, but became so, and more and more so, as they reached the denser parts of the atmosphere, until they exploded, or burst asunder; and that they consisted of luminous vapor, such as, after explosion, remained suspended in the air."

But the most probable conjecture seems to be, that these meteors are electrical phenomena.

The state of the atmosphere is to be considered. The weather was warm for some time previous to the late display. On the day preceding, it was almost sultry. In the afternoon, there were gusts of wind, attended with sudden showers of rain, and lightning. "The atmosphere seemed to be saturated with electricity."

To account for these meteors on the principles of electricity is not *new*. Dr. Rees informs us, that "Dr.

Blagden proceeds to explain these meteors on the hypothesis, that they are electrical phenomena. His arguments are, 1st, from the great rapidity of their motion, which seems to exceed any other we are acquainted with, besides electricity; 2dly, from certain electrical phenomena, which sometimes accompany these meteors; and, 3dly, from the connection which they have with the aurora borealis. Dr. Blagden concludes, that there are three regions of the atmosphere, distinguished by electrical phenomena peculiar to each; 1st, the lowest region, in which the thunder and lightning occur; 2dly, the middle region, where the fireballs and shooting stars are observed; and, 3dly, the highest region, where the aurora borealis displays a peculiar kind of electrical agency." It is worthy of remark, that many accounts mention flashes of lightning during the late display of meteors. It is very probable, that the great meteor which passed over England, on the 18th of August, 1783, was an electrical phenomenon. It went with immense rapidity, more than 1000 miles in about half a minute.

Is it a fact, that stones have fallen from the visible heavens to the Earth? How was the event of their falling first received? Where do we find the earliest account of these falling stones? Have there been many accounts of these stones handed down to us from antiquity? Can you name some instances of these stones falling in modern times? Has New England afforded any well-authenticated account of these wonderful phenomena? Can you give some account of the meteor which appeared in Connecticut in 1807, and of the stones which fell on that occasion? What are some of the opinions respecting the origin of falling stones? What appears to be the most plausible opinion? Are there luminous meteors different in their origin from aerolithes or falling stones? Can you give an account of the meteors witnessed by Humboldt and Bonpland at Cumana in South America? What other remarkable displays of luminous meteors can you mention? What noted exhibition of meteors will the citizens of these United States long remember? What is worthy of notice and philosophical inquiry in the several instances of these meteors in modern times? How have different authors accounted for these meteors? What seems to be the most probable conjecture respecting them? What is Dr. Blagden's hypothesis?

CHAPTER XVII.

Artificial Globes.

ARTIFICIAL globes are spheres intended to represent the Earth and the visible heavens. They are of two kinds, *terrestrial* and *celestial*. On the terrestrial is represented the Earth's surface, diversified with the principal divisions of land and water, forming a spherical map of the whole; on the celestial, the visible heavens distinguished into constellations. For convenient use, a globe of either kind is placed upon a frame. On each, the great imaginary circles of the sphere, the tropics, and the polar circles, are represented.

The *equator* on a terrestrial globe is about one eighth of an inch broad, graduated for longitude 180° each way from the first meridian.

The *ecliptic*, about the same breadth, inclined to the equator in an angle of $23^{\circ} 28'$, is divided into signs, and subdivided into degrees, commencing at the first of Aries.

The *brazen meridian* is a circle of brass encompassing the globe from north to south, crossing the equator at right angles. The upper semicircle of this is graduated, beginning at the equator, and ending with 90° at the poles. The graduation of the lower semicircle begins at the poles, and ends with 90° at the equator. Besides this, there are other meridians drawn on the globe with dark lines, meeting at the poles. 12 of these, 24 semicircles, form the hour lines. The meridian passing through the equinoctial points is the *equinoctial colure*. Another, passing through the solstitial points, is the *solstitial colure*. The *horizon* is represented by a broad circle of wood, divided into four points, *east, west, north, south*, called the *cardinal points*. Next to the globe, on this, are the *amplitudes*,

graduated into four nineties, commencing at the east and west points. Without these are the *azimuths*, graduated into four nineties, beginning at the poles. Next to these are the 32 *points* of the compass, containing $11^{\circ} 15'$ each. Beyond these are the 12 signs, each having its appropriate name, figure, and character; and each graduated as in the ecliptic.

On the exterior circle of the horizon are represented the days of the months, adjusted to the signs, so that each day of a month is placed at the degree of the sign in which the Sun is at that time. Small figures between the divisions of days show how much the Sun is fast or slow of clock, marked (+) when the Sun is slow of clock, and (—) when it is fast.

The *two tropics* are represented on a terrestrial globe by dark or colored lines, $23^{\circ} 28'$ from the equator; the *two polar circles* in the same manner $23^{\circ} 28'$ from the poles.

Parallels of latitude, drawn to each 10° , are peculiar to this globe.

An hour circle, about two inches diameter at the north pole, is divided into 24 parts, and numbered into two twelves, with a movable index attached to the brazen meridian pointing to the time. A similar circle at the south pole is divided and numbered in the same manner, but without an index,—time being computed from the brazen meridian.

Some diversity is to be found in globes. The description here given answers to Gardener's globe.

Attached to some globes is a *quadrant of altitude*, a thin strip of brass, graduated into 90 parts, equal to 90° of a great circle.

The circles of an artificial globe are best learned by inspection with the globe at hand.

To use a globe, stand facing the graduated side of the brazen meridian.

To *rectify a globe* for the latitude of a place, elevate the nearest pole equal to the latitude of that place. When thus rectified, such place, brought to the brazen meridian, is at the top or highest point of the globe.

Suppose you would rectify for the latitude of Washington ; raise the north pole till $38^{\circ} 53'$ on the lower semicircle of the brazen meridian comes to the upper side of the wooden horizon ; then Washington, brought to the meridian, will be at the highest point of the globe.

The celestial globe has a representation of the zodiac. It has, also, besides the circles common to this and the terrestrial globe, secondaries, drawn perpendicular to the ecliptic at every ten degrees, meeting at the poles. The great circles are here graduated, as on the terrestrial globe. Except on the equator, the degrees are numbered in the same manner. This, beginning at the first of Aries, is numbered for right ascension eastward round the globe.

In the solution of problems on artificial globes, great accuracy is not to be expected. Important *general knowledge*, however, may be obtained.

Problems to be solved on the Terrestrial Globe.

PROBLEM I.

To find the latitude and longitude of a place.

Bring the place to the brazen meridian. On the meridian above it is the latitude. The longitude is found on the equator at its intersection with the meridian.

What are the latitude and longitude of Jerusalem ?

Answer, about 32° N. 35° E.*

Find the latitude and longitude of Canton in China.

23° N. 113° E.

PROBLEM II.

When the latitude and longitude of a place are given, to find the place.

Find the longitude on the equator. Bring this to the

* Longitude, in these problems, is reckoned from Greenwich, it being so placed on the globes.

brazen meridian. Directly under the latitude given is the place sought.

What place is in $42^{\circ} 23' \text{ N. } 71^{\circ} 4' \text{ W.}$

Boston.

What place is in $34^{\circ} 26' \text{ S. } 18^{\circ} 23' \text{ E.}$

Cape of Good Hope.

PROBLEM III.

To find the difference of latitude between two places.

Bring each to the brazen meridian, and find the latitude. If both be of the same name, north or south, the less subtracted from the greater leaves the difference of latitude. If the latitudes be of different names, one north and the other south, their sum is the distance sought.

Give the difference of latitude between Washington and New York. $1^{\circ} 49'.$

What is the difference of latitude between Philadelphia and Buenos Ayres? $74^{\circ} 34'.$

PROBLEM IV.

To find the difference of longitude between two places.

Find the longitude of each, according to the direction before given. If the longitudes be of the same name, east or west, their difference is the answer. When they are of different names, their sum, if less than 180° , is the result sought. If the sum be more than 180° , subtract it from 360° ; the remainder is the difference of longitude required.

Give the difference of longitude between Portsmouth, N. H., and Cadiz? $64^{\circ} 30'.$

What is the difference of longitude between St. Lewis and Paris? $92^{\circ}.$

Find the difference of longitude between Cincinnati and Batavia. $168^{\circ}.$

PROBLEM V.

To find the distance between two places on the globe.

With a pair of dividers gently applied to the globe, or the straight edge of a piece of paper, take the extent between the places. With this extent applied to the equator, note the number of degrees, which, multiplied by $69\frac{1}{2}$, give the distance in statute miles; by 60, the distance in geographical miles.

When a globe has a quadrant of altitude, the number of degrees between places may be ascertained by only taking the distance on the quadrant, without reference to the equator.

What is the distance from Boston to London? About 3340 miles.

What is the distance from Cape St. Roque to Cape Verd? 1900 statute miles, 1640 geographical miles.

PROBLEM VI.

The hour of the day at a place being given, to find the time at any other place.

The place where the hour is given being brought to the brazen meridian, and the index set at the hour, turn the globe till the other place comes to the meridian; the index will show the hour.

What is the time at Cairo, in Egypt, when it is 9 o'clock, A. M., at Boston? 3 h. 47 m., P. M.

When it is noon at Washington, what is the time at the Sandwich Islands? 6 h. 45 m., A. M.

PROBLEM VII.

To find the Sun's place in the ecliptic.

The day of the month being found on the horizon, opposite to this, in the adjacent sign, is the degree of the Sun's place. The same sign and degree found in the ecliptic show the Sun's place.

The Sun's place in the ecliptic on the 4th of July is 12° of Cancer.

PROBLEM VIII.

On a given day to find the declination of the Sun.

On the brazen meridian, directly over the Sun's place in the ecliptic, brought to that meridian, is the Sun's declination.

On the 1st day of May, the declination of the Sun is 15° N.

There is an *analemma* on the globe, where the declination for each day is set against the days of the months.

PROBLEM IX.

To find on a given day at what places the Sun is vertical.

The degree of the Sun's declination being found on the brazen meridian, turn the globe round, and to all places coming under that degree the Sun is vertical.

On the 28th of August, the Sun is vertical to the northern part of the Colombian republic, to Guinea, Abyssinia, the southern part of Hindostan, and Malacca.

PROBLEM X.

To find at any given hour where the Sun is vertical.

The place where the hour is given being brought to the brazen meridian, and the index set at the given hour, turn the globe westward for the forenoon, eastward for the afternoon, till the index points to 12; under the degree of the Sun's declination is the place sought.

Where is the Sun vertical on the 16th of April, when the time is 11 o'clock, A. M., at Washington?

Near the mouth of the river Orinoco, in the Colombian republic.

PROBLEM XI.

To find, at any given place, and time of year, what hour the Sun rises and sets; also the length of the day and night.

The globe being rectified for the latitude of the place, find the Sun's place in the ecliptic, and bring it to the brazen meridian. Set the index at 12. Turn the globe eastward till the Sun's place comes to the horizon, the index will point to the time of the Sun's rising. Turn the Sun's place westward to the horizon, the index will show the time of his setting.

Double the time of the Sun's setting for the length of the day; of his rising, for the length of the night.

On the 1st of June, the Sun rises at Boston about 4 h. 30 m., sets about 7 h. 30 m. The length of the day is 15 hours; of the night, 9 hours.

PROBLEM XII.

At any place, to find at a given time where the Sun is rising, and where setting; where it is noon, and where midnight.

When the Sun is north declination, elevate the north pole, when it is south declination, the south pole, equal to the declination, and bring the place where the Sun is vertical at the hour to the meridian. The Sun appears rising to places at the western semicircle of the horizon; setting, at the eastern. It is noon at the meridian above the horizon; midnight at the meridian below.

On the 1st of January, 0 h. 30 m., P. M., at Washington, the Sun is rising at the western Sandwich Islands; also a little to the west of the Friendly Islands, and New Zealand. It is noon at Hudson's Bay, Upper Canada, Michigan Territory, Indiana, Kentucky, Tennessee, Western Georgia, Gulf of Mexico, and Guatemala. The Sun is setting at Cape Farewell; in Africa, near the mouth of the Gambia, Liberia, and the Cape of Good Hope.

PROBLEM XIII.

To find, by the globe and the table of longitude, how fast any place moves by the revolution of the Earth on its axis.

Find the latitude of the place by the globe, and the number of miles in a degree by the table. These, multiplied by 15, give the answer required.

Caraccas moves 1025 miles an hour.

Nova Zembla moves 217 miles an hour.

Problems to be solved by the Celestial Globe.

PROBLEM I.

To find the declination of a star.

Bring the star to the brazen meridian; directly over it, on the meridian, is the degree of its declination.

The declination of Sirius is $16^{\circ} 30'$ S.

The declination of Arcturus is $20^{\circ} 20'$ N.

The declination of the Sun is found on this as on the terrestrial globe.

PROBLEM II.

To find the right ascension of a star or the Sun.

Bring the star or the Sun's place to the brazen meridian. At the intersection of the equator and the meridian, on the equator, is the degree of right ascension.

The right ascension of Regulus is $149^{\circ} 30'$.

The right ascension of the Sun, on the 4th day of July, is 102° .

PROBLEM III.

To find a star on the globe, when its declination and right ascension are given.

Bring the right ascension to the brazen meridian. Under this, at the declination, the star will be found.

What star is $5^{\circ} 40'$ N. declination, 112° right ascension? Procyon.

PROBLEM IV.

At any place, the time of year being given, to find at what hour any star will rise, be on the meridian, and set.

The globe being rectified for the latitude of the place, bring the Sun's place in the ecliptic to the brazen meridian, and set the index at 12. Turn the globe till the star comes to the horizon eastward, the index will show the time of its rising. Bring it to the meridian, the index will point to the time. Turn it to the horizon westward, the index will show the time of its setting.

At Boston, on the 20th of January, the Sun rises at 5 h. 45 m., P. M., is on the meridian at 10 h. 30 m., P. M., and sets at 3 h. 15 m., A. M., of the 21st.

PROBLEM V.

The altitude of a star being given, to find the time of night at a place proposed.

Rectify the globe for the latitude of the place. The Sun's place in the ecliptic being brought to the brazen meridian, set the index at 12. Turn the globe till the star comes to the altitude proposed; the index will point to the time.

When Arcturus is 10° above the western horizon on 31st of August, what is the time of night at Boston? 9 h. 45 m., P. M.

PROBLEM VI.

The latitude of a place being given, to adjust the globe so as to represent the appearance of the heavens at any proposed hour of the night.

The globe being rectified for the latitude of the place, and the Sun's place in the ecliptic brought to the brazen meridian, set the index at 12. Turn the globe eastward for the forenoon, westward for the afternoon, till the index points to the given hour. The ap-

pearance of the heavens, at the time proposed, will then be represented by the globe.

Show the appearance of the heavens at Washington, March the 20th, at 7 o'clock, P. M.

Arcturus is rising at 25° north of east. Procyon has nearly arrived at the meridian; Sirius is a little past; the bright constellation Orion, a little farther past. Capella, to the north, is nearly in the same rank. A little farther in western declination are Aldebaran, the Hyades, and Pleiades.

The appearance of the heavens at Boston, on the 23d of September, at 7 h. 40 m., P. M., is required.

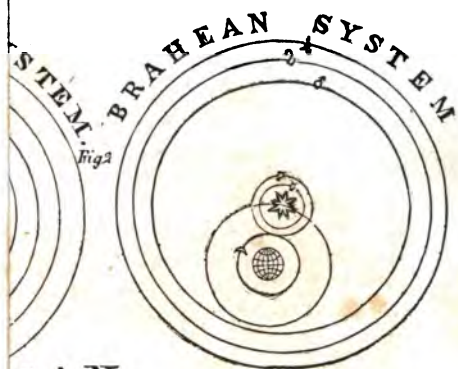
Fomalhaut may be seen a little above the eastern horizon. Altair is on the meridian; Vega a little declined from the zenith. The constellations Corona borealis, and Bootes, with bright Arcturus fast declining, adorn the hemisphere to the west.

•

A familiar use of the globes is recommended. By it the knowledge of the student in geography and astronomy will be greatly improved. By it he will be more interested in contemplating the visible heavens—an amusement innocent and delightful for the evening or the most lonely hours of night. But, infinitely more important! by observation on the celestial canopy; by the greatness of the scenery presented,—he must be irresistibly led to the contemplation of the immensity and infinite goodness of JEHOVAH, THE AUTHOR AND GOVERNOR OF ALL.

What are artificial globes? Of how many kinds are they? What is represented on the terrestrial globe? What on the celestial? How is the equator represented on the terrestrial globe, and how is it graduated? How is the ecliptic represented and divided? What is the brazen meridian? How is it graduated? How is the horizon represented? How do you explain the different circles on the horizon? What other circles are to be seen on the terrestrial globe? How do you explain the hour circles? What is it to rectify the globe for the latitude of a place? What circles are peculiar to the celestial globe? How are degrees numbered on the equator of this globe?

PLATE I.



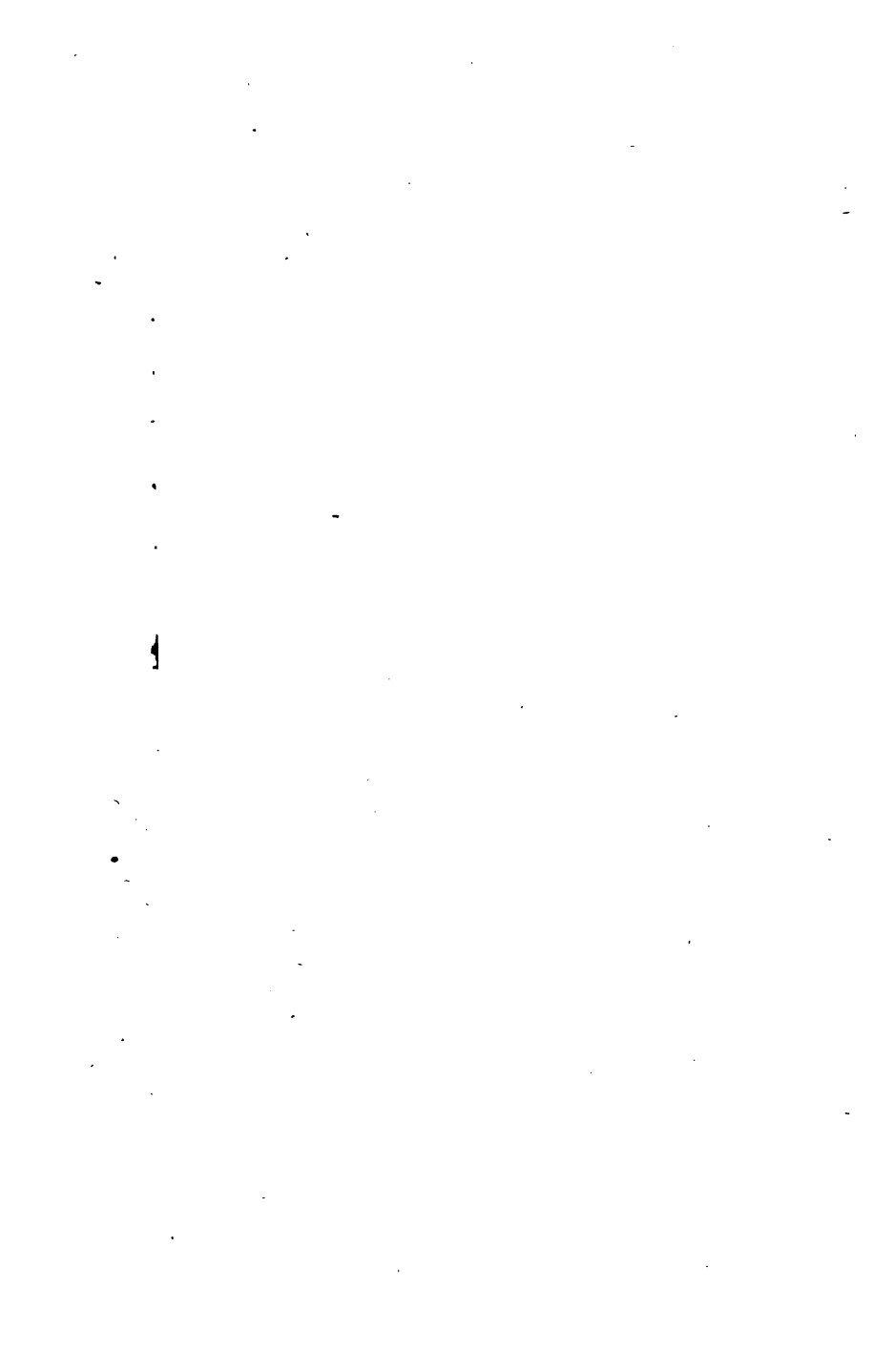
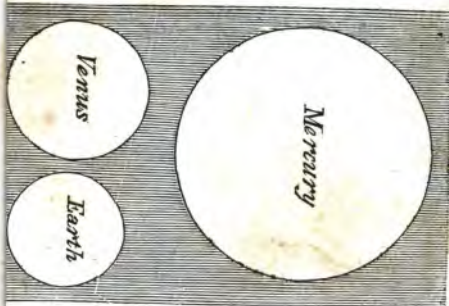


PLATE II.

seen from the different planets.

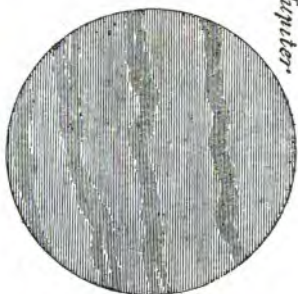


red with the Sun at 15 inches diameter.

Mercury
Venus
Earth
Mars
Vesta
Juno
Ceres
Pallas



Jupiter



Herschel



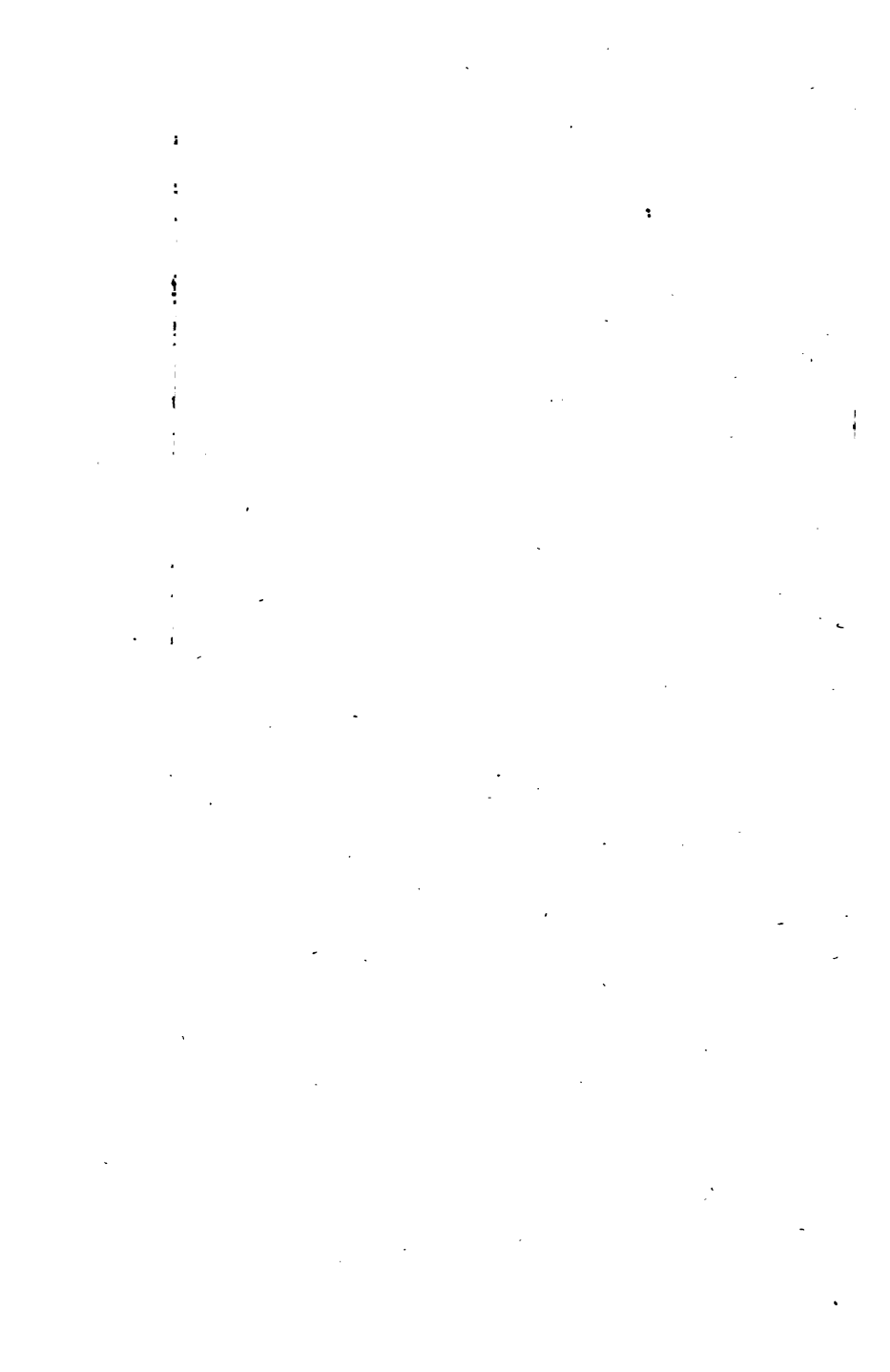
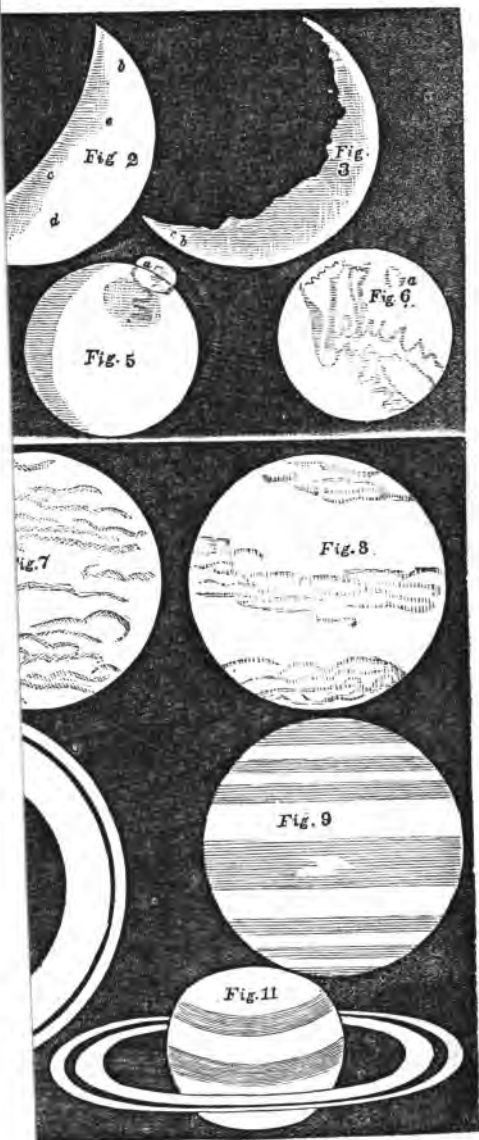


PLATE III.



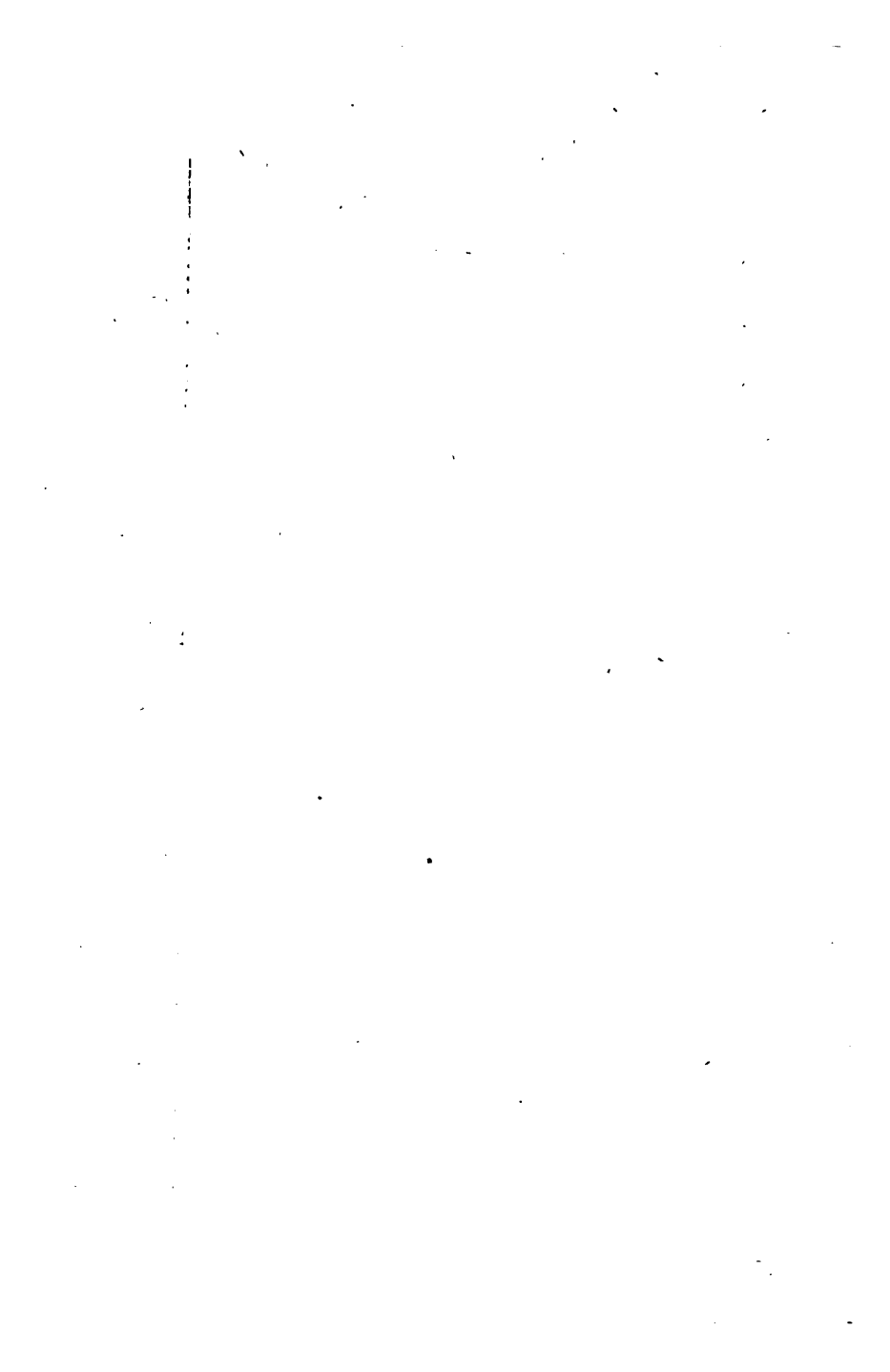
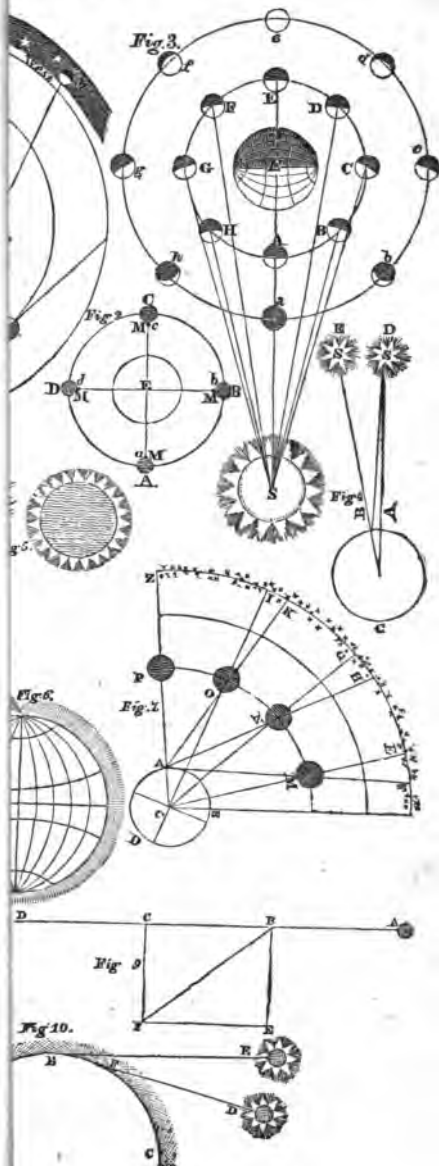


PLATE IV.
W AND FULL MOON.



PLATE V.



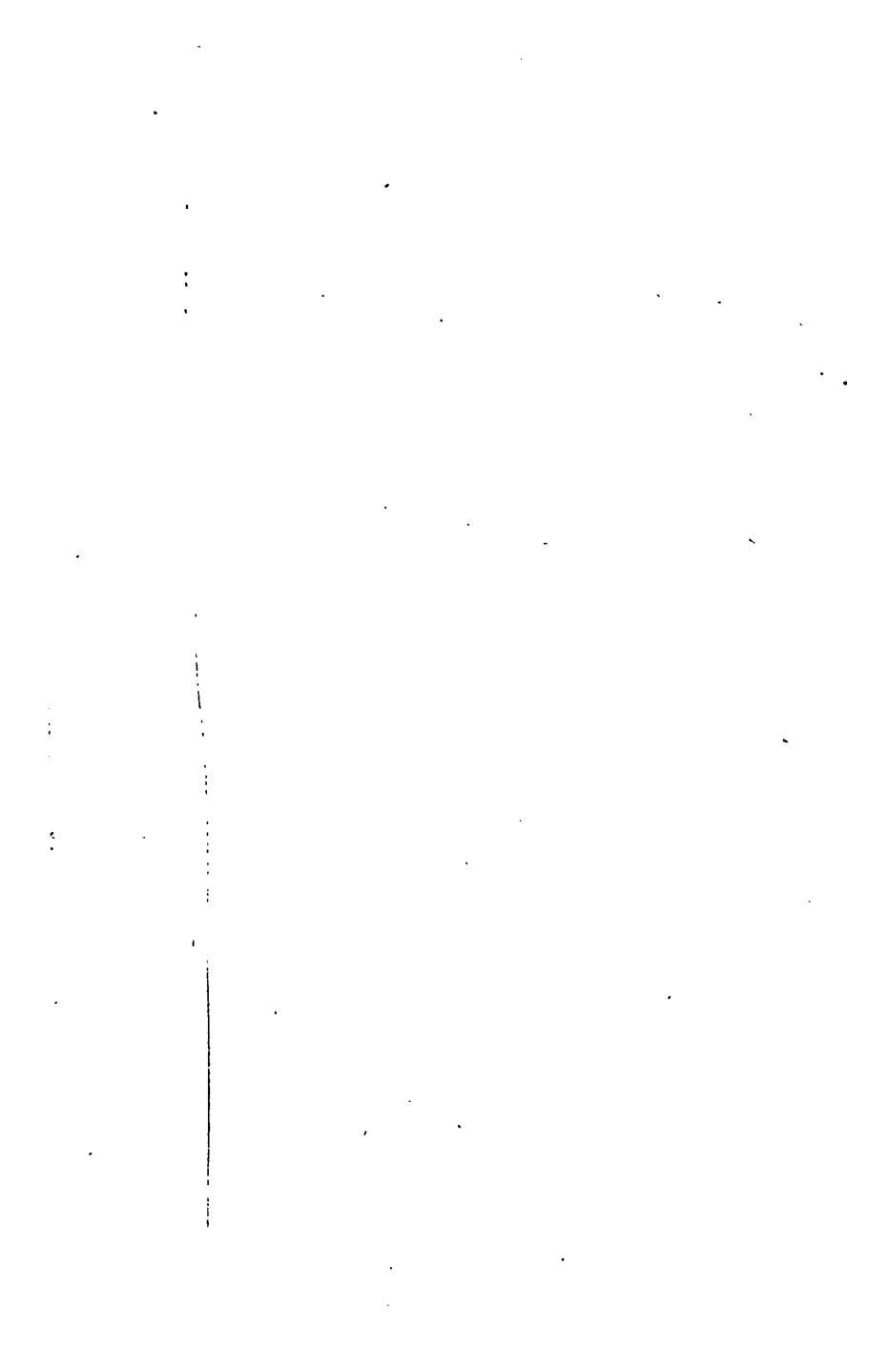


PLATE VI.

Fig. 2.

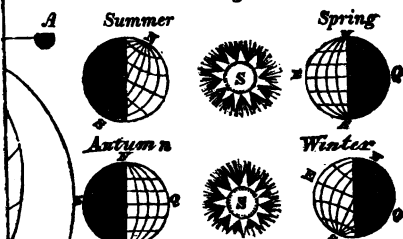


Fig. 4.



Fig. 5.



Fig. 7.

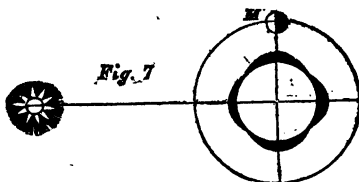


Fig. 9.

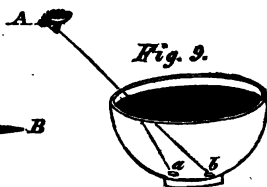
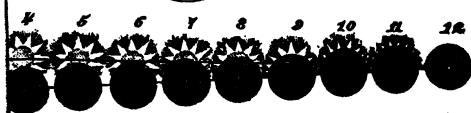
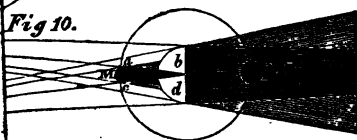


Fig. 10.



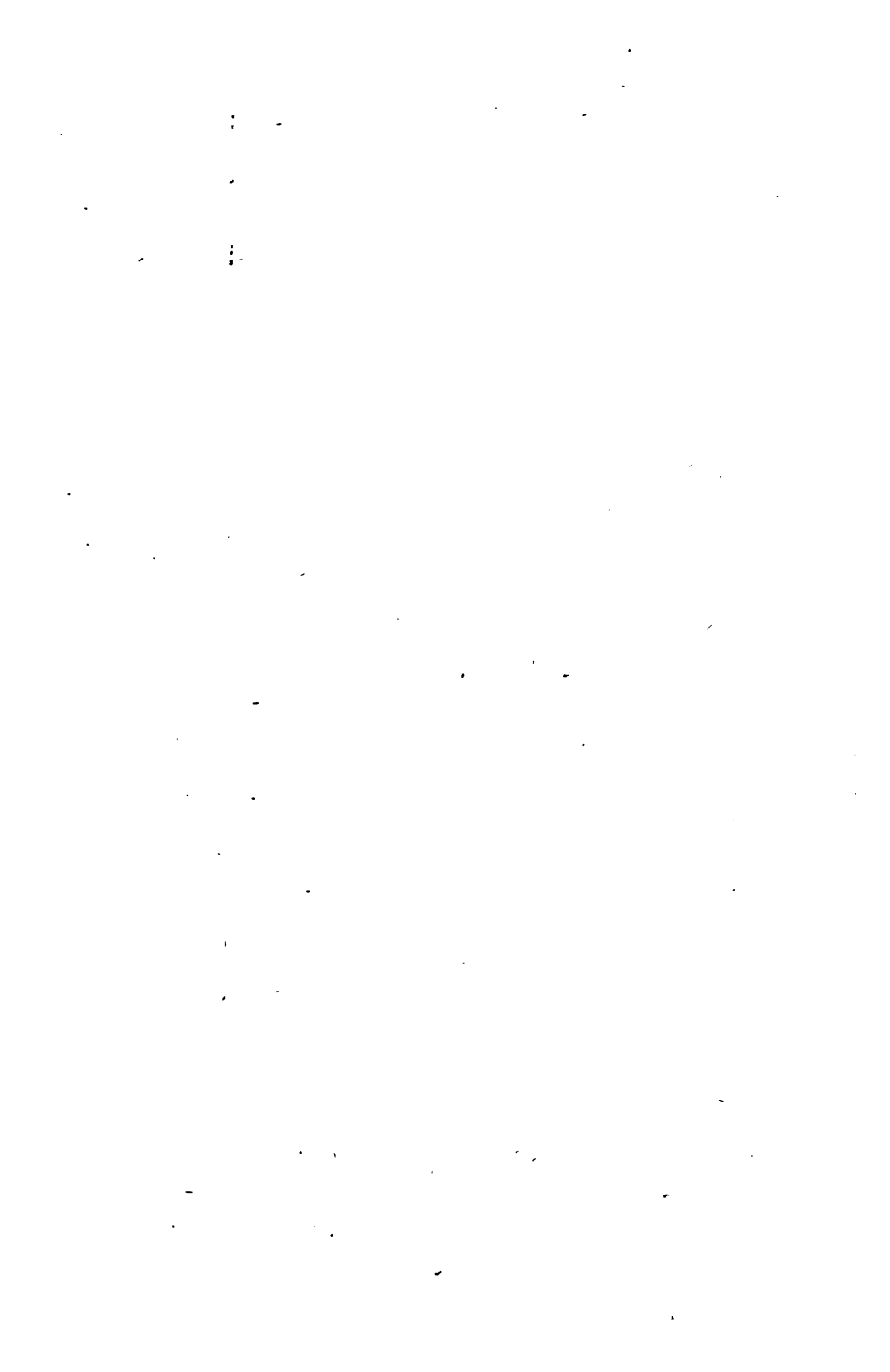


PLATE VII.

Phenix, the Phenix.





PLATE IV.
W AND FULL MOON.





PLATE V.

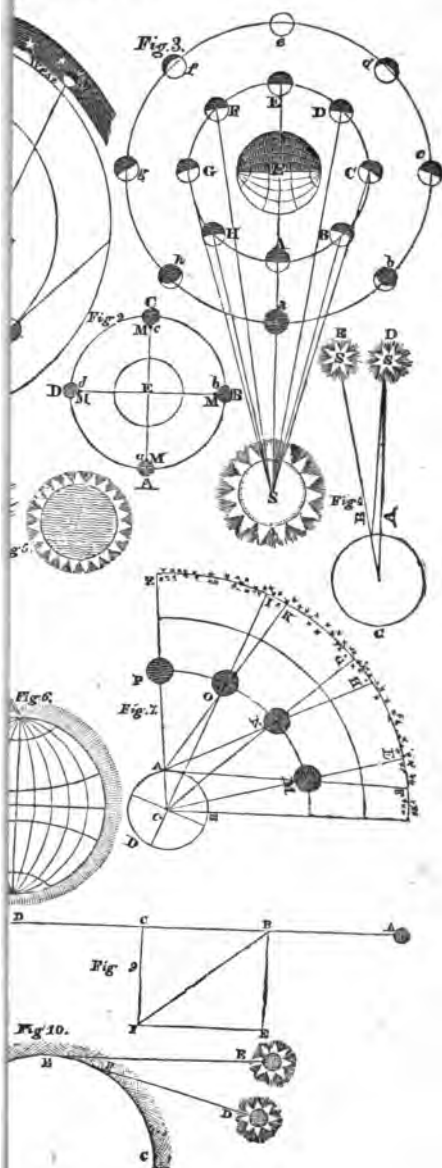




PLATE VI.

Fig. 2.

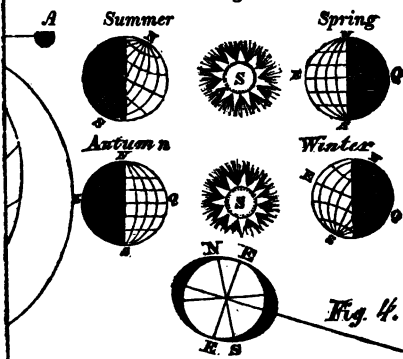


Fig. 4.

Fig. 5.



Fig. 7.

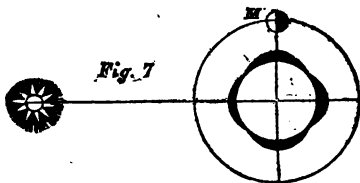


Fig. 9.

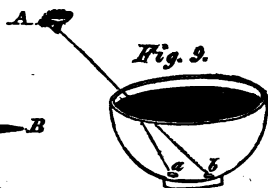


Fig. 10.

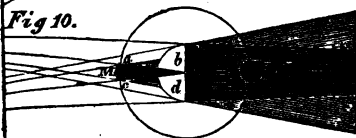
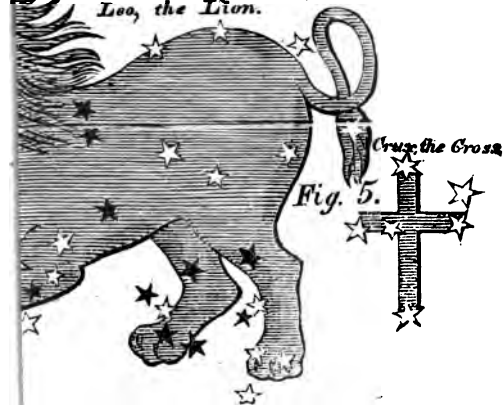




PLATE VII.

Phenix, the Phenix.



Stars.

Nebulous Stars.



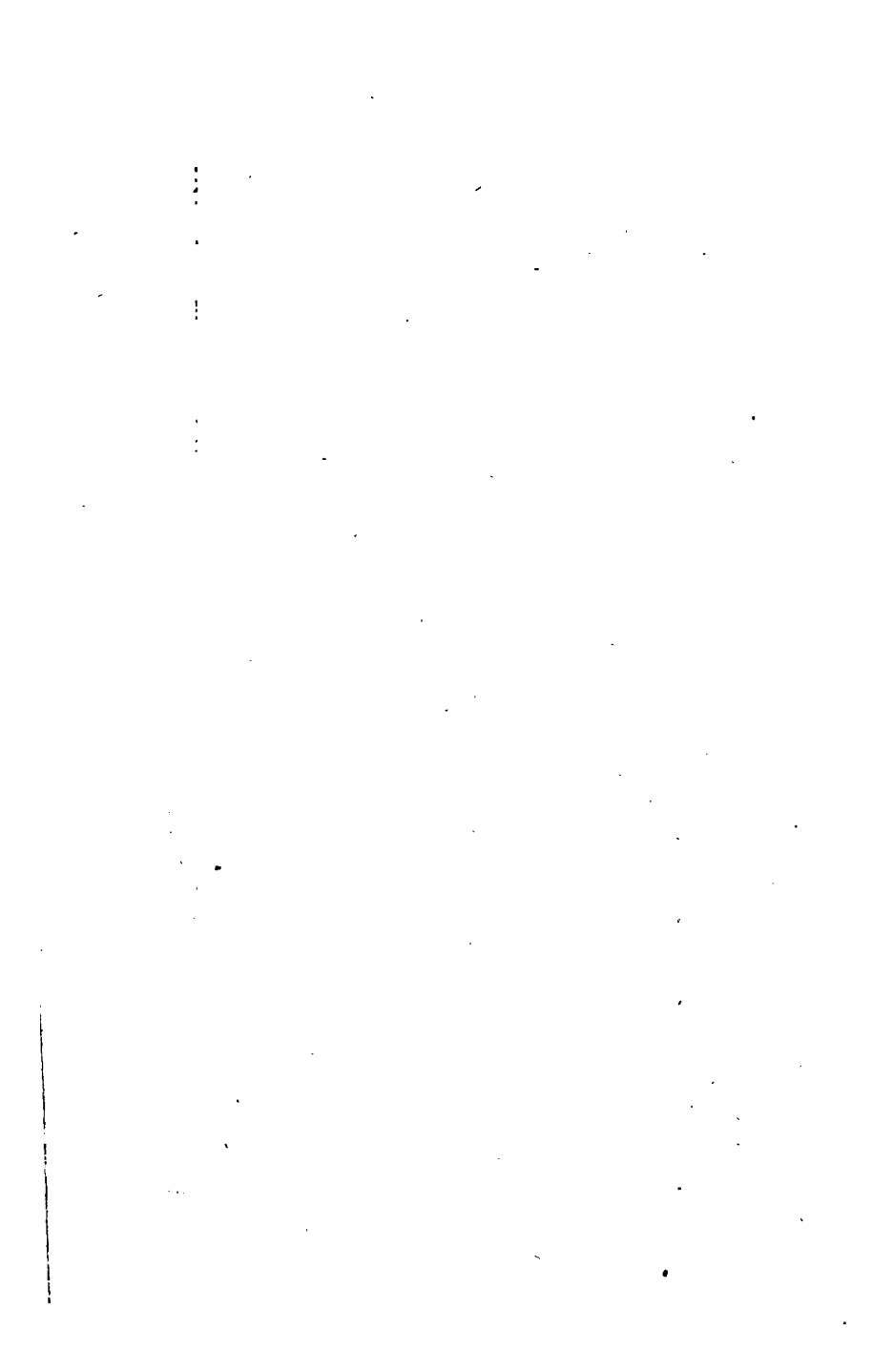
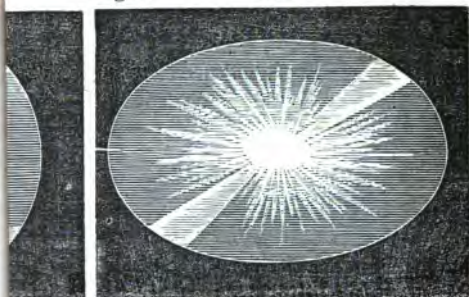


PLATE VIII.

Fig. 2.

Nebulæ.



tes.

Fig. 4.

Treple Star in Monoceros.

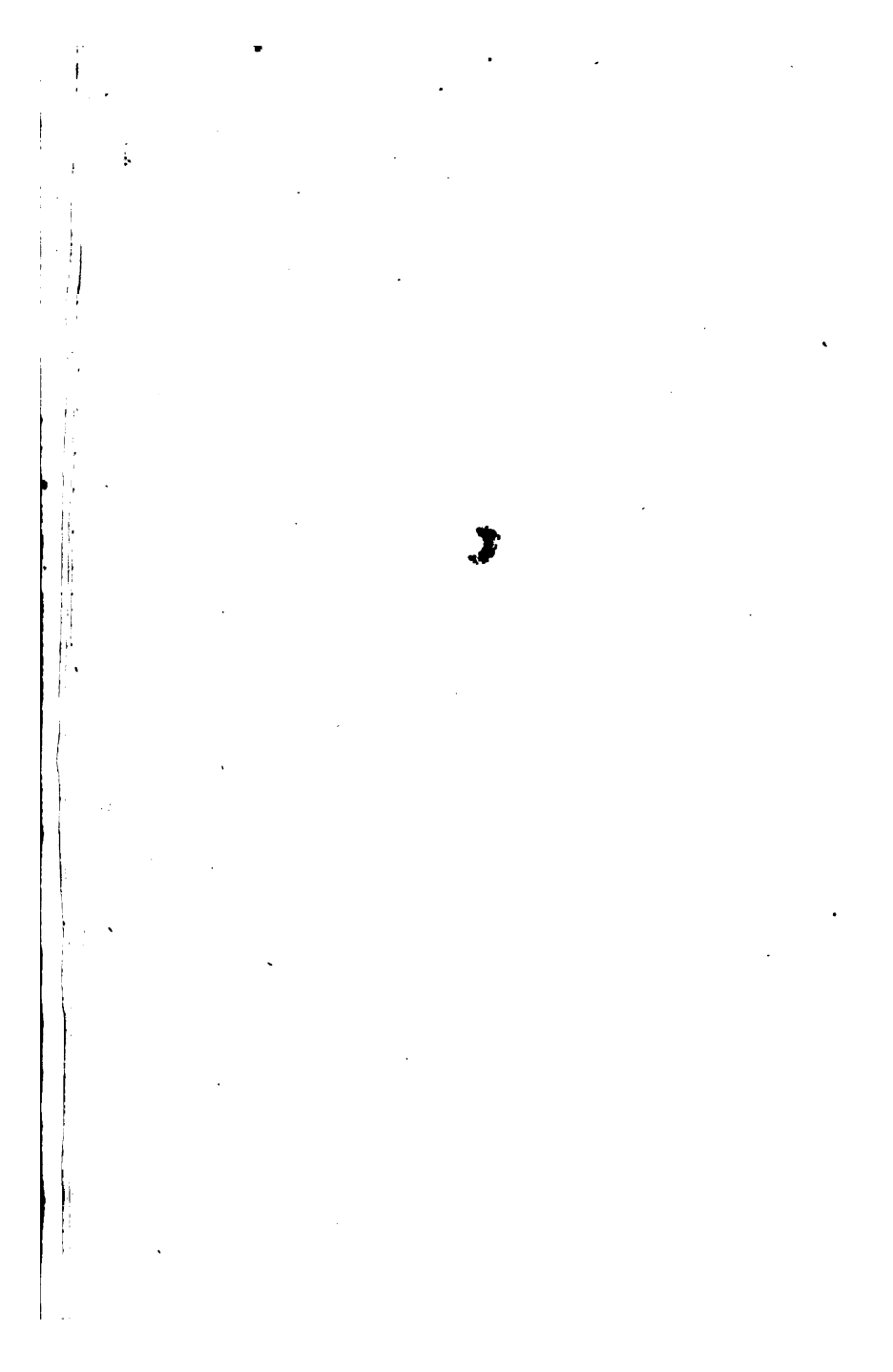


3.

Fig. 6.

The Constellation Canis Major.

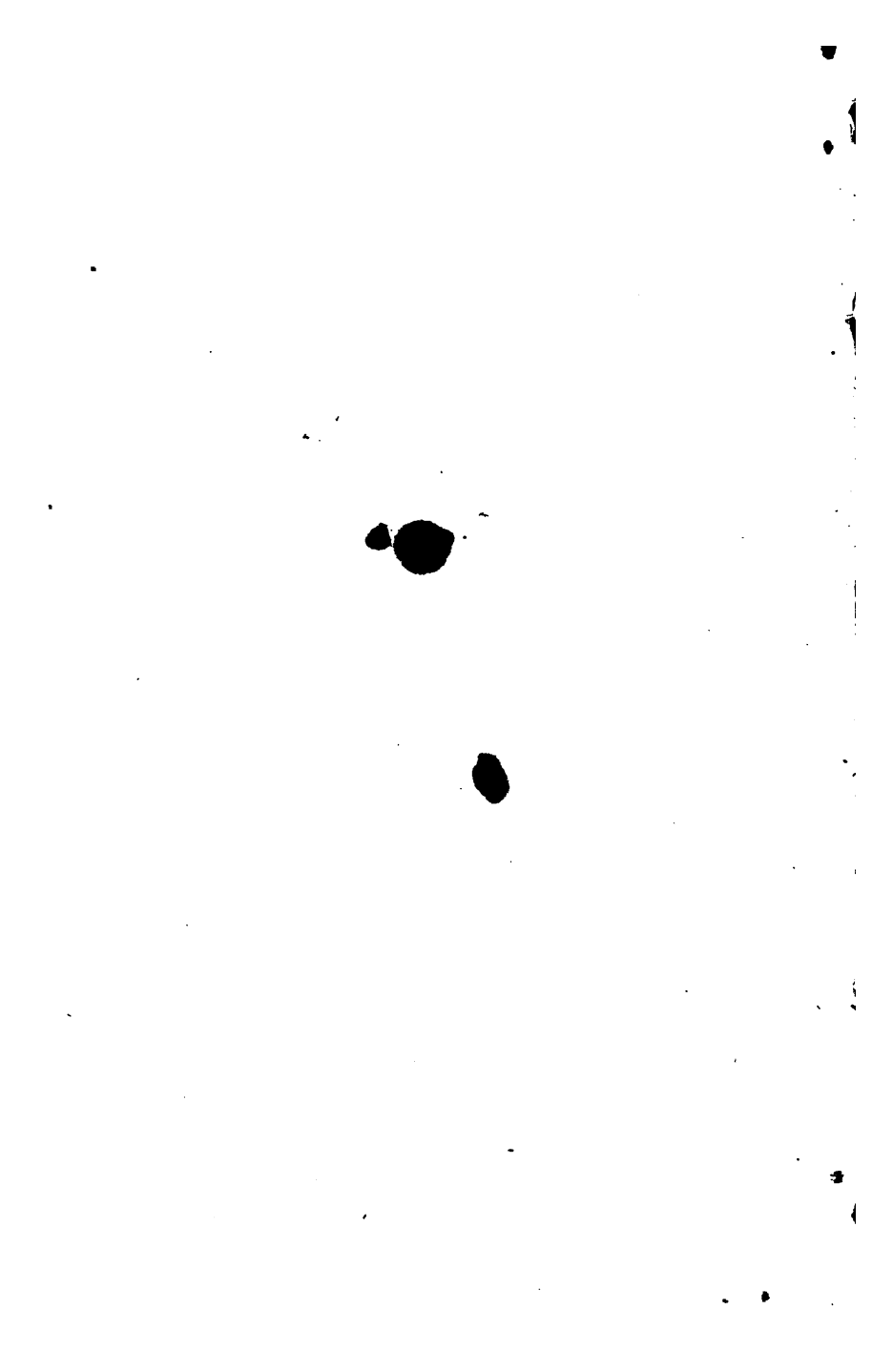






2.





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